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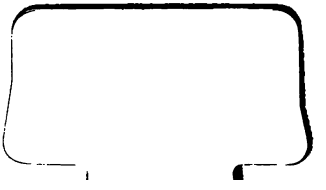
CHEMISTRY OF THE MINE



Chemistry of the Mine

OR THE

MINERS' POCKET COMPANION.

A TREATISE ON THE ATMOSPHERE, THE GASES MET WITH IN MINES, THE FORMATION OF MINERALS, THE METHOD EMPLOYED TO WORK THEM, THE VENTILATION OF MINES, OUTLINES ON ANGULAR SURVEYING, AND THE PROPERTIES OF MECHANICAL FORCE,

BY

R. R. HODGSON, M.E., C.C.M.,

BROTTON, SALTBURN-BY-THE-SEA.

RIC... MEDICA
FEB 1882
BODLEIAN.

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LONDON:
ELLIOTT STOCK, 62, PATERNOSTER ROW.

DARLINGTON:
EDWARD C. ETTY, BRIDGE ROW.

1881.

193. g. 158.

EDWARD C. BETTY, PRINTER, BRIDGE ROW, DARLINGTON.

PREFACE.

In submitting this work to the consideration of all who feel an interest in the safety and well-being of the miner, to the miner himself, and the mine-owner in particular, the author feels that he is only discharging a duty he owes to a deserving cause, the more efficient management of mines, and in order to prevent the sacrifice of life and property so far as human appliances can be brought to bear upon this section of our national industry.

The experience of all practical colliery managers, who have given the subject their careful attention, goes to prove that fully 90 per cent. of the colliery explosions of this country can be traced directly to the defective management of the mines. If this be true, it is evident that we must look to a change from the theoretical to the practical management of the mines for the remedy.

Many valuable works are in circulation bearing on the subject of mining, but somehow they all fail to define the cause and lay down a principle for the prevention of those frightful disasters—colliery explosions—that so rapidly succeed each other, carrying with them a thrill of horror through the civilized world. It is to meet this deficiency, and combine the theory with the practical experience of the miner, in order to fit him for the important duties of a colliery manager, that this work is produced.

To accomplish this, and to initiate the young student into the higher principles of the office, the following subjects are arranged in the order in which they stand related to the underground management of mines: (1) The atmosphere—its composition, properties, and general effects upon surrounding objects; (2) the law of gaseous diffusion—the order and proportions in which they unite with each other; (3) the gases met with in mines—their composition, density, specific gravity, general properties, and how they should be governed; (4) the ventilation of mines—the distribution of the air current, the measurement of its volume, the friction it encounters in its passage through the mine, and the cause of its motion; (5) the laws of motion—common, central, and incline; (6) the safety lamp—its construction and the way it should be used;

(7) the daily inspection of mines—the proper use of the thermometer, barometer, water gauge, and anemometer; (8) explosive substances for blasting purposes—gunpowder, gun-cotton, and nitro-glycerine—their properties and general effects on the ventilation; (9) the different methods employed to work mines—the pillar and stall and long-wall principles; (10) the formation and composition of rocks, minerals, and water; (11) angular surveying—the Gunter's chain as a measuring instrument, its dimensions and adaptation to the work; the theodolite, its adjustments and how to be used; and (12) the mechanical forces required, and how to find them, for pumping and winding purposes.

To suit the convenience and aid the student to fully comprehend the several principles above named, the work is illustrated with 23 engravings, and contains a series of 138 exercises.

Believing this treatise to contain sufficient information on mining in general to enable the student to raise himself to those offices of the mine for which his practical experience so well befits him, the author contents himself with the humble effort he has made to bring about this desirable change, and therefore dedicates his work to the best interest of the miners and mine-owners of the United Kingdom of Great Britain and Ireland.

BROTTON, SALTBURN-BY-THE-SEA,
1880.

BAROMETER

Fig 1

SYPHON

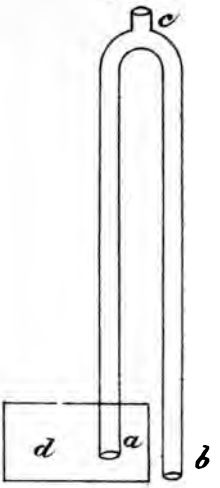


Fig 2

THERMOMETER

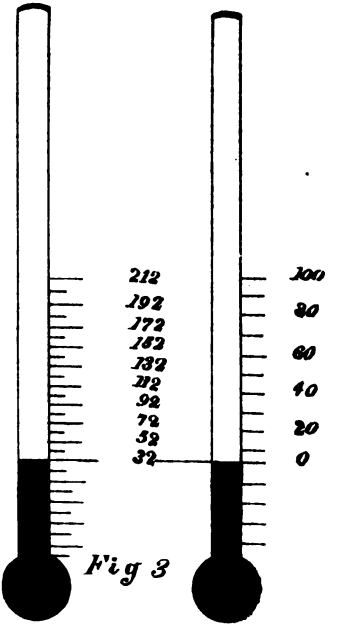


Fig 3

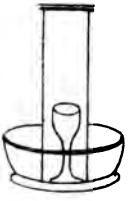


Fig 4

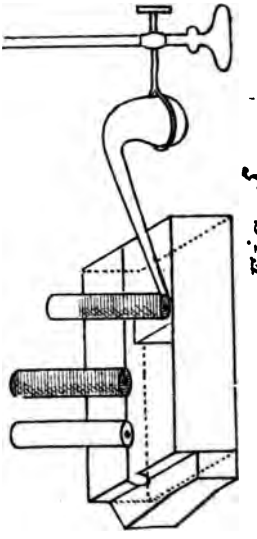


Fig 5

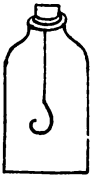


Fig 6.

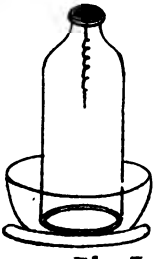


Fig 7

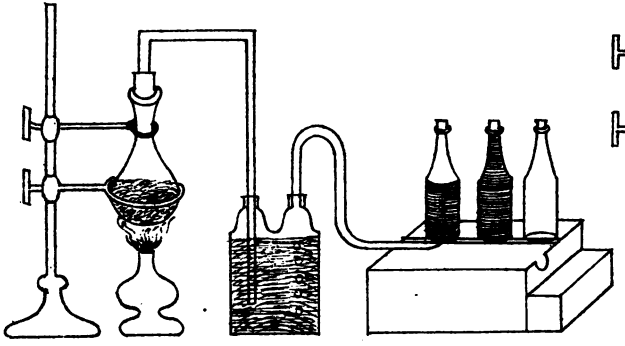


Fig 13

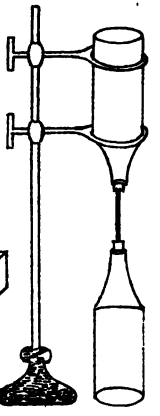


Fig 11.

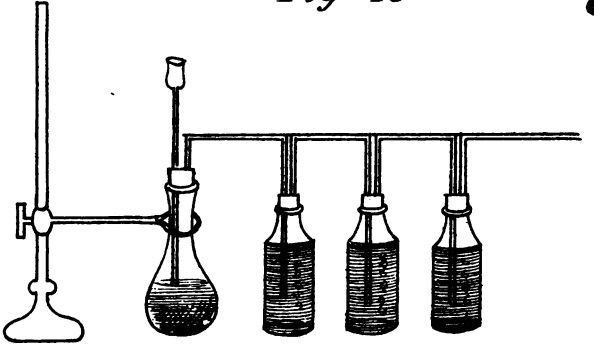
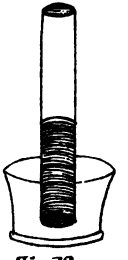


Fig 14



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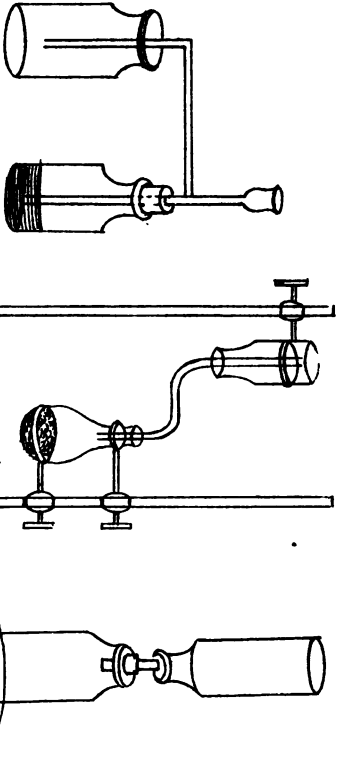


Fig 9

Fig 8

Fig 10

SAFETY LAMP

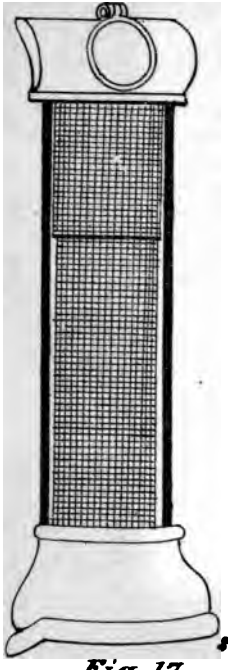


Fig. 17

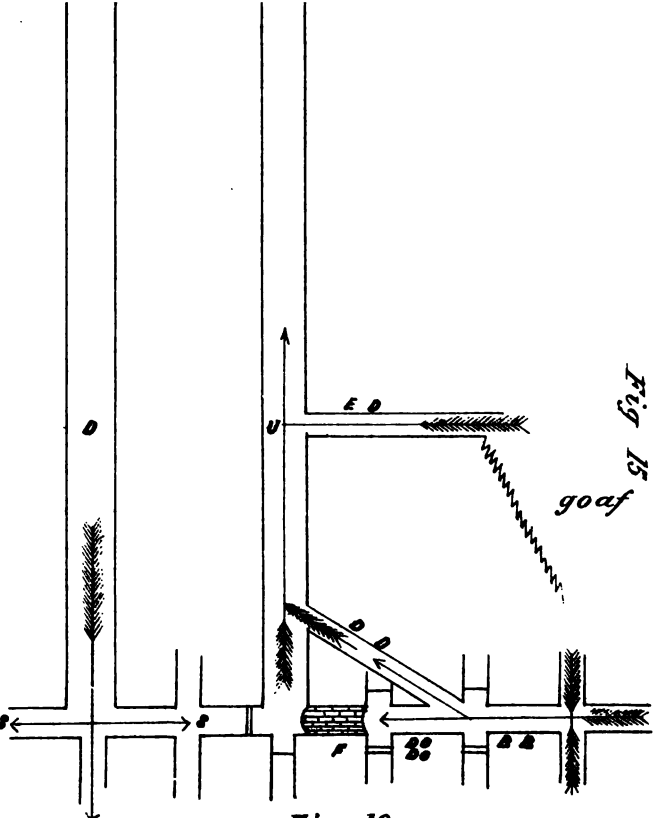
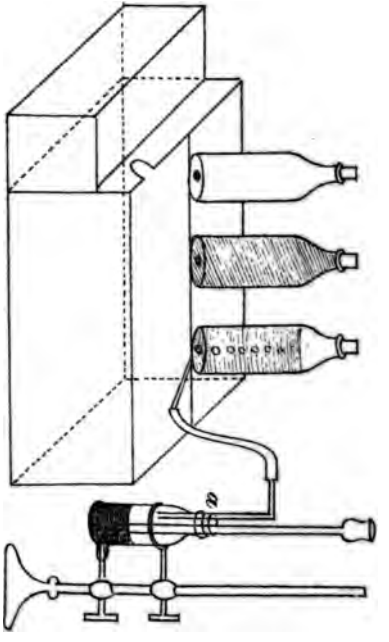


Fig 18



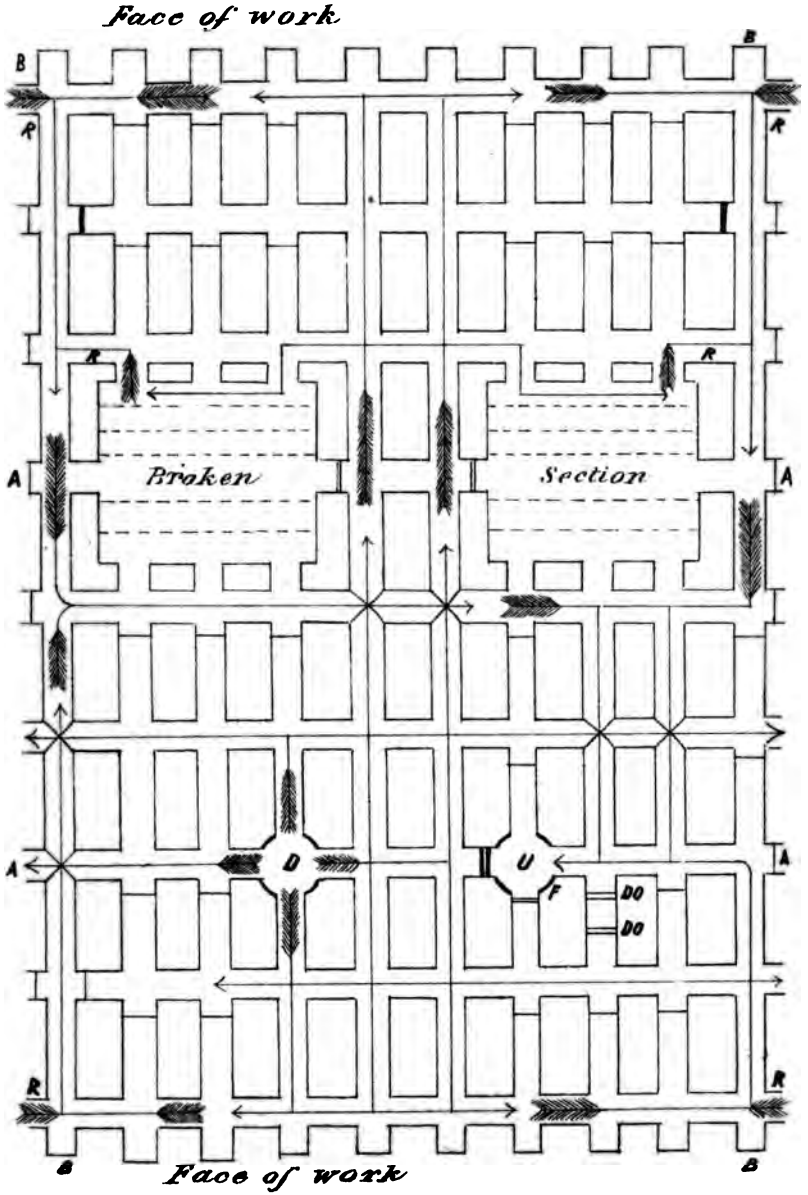


Fig 18

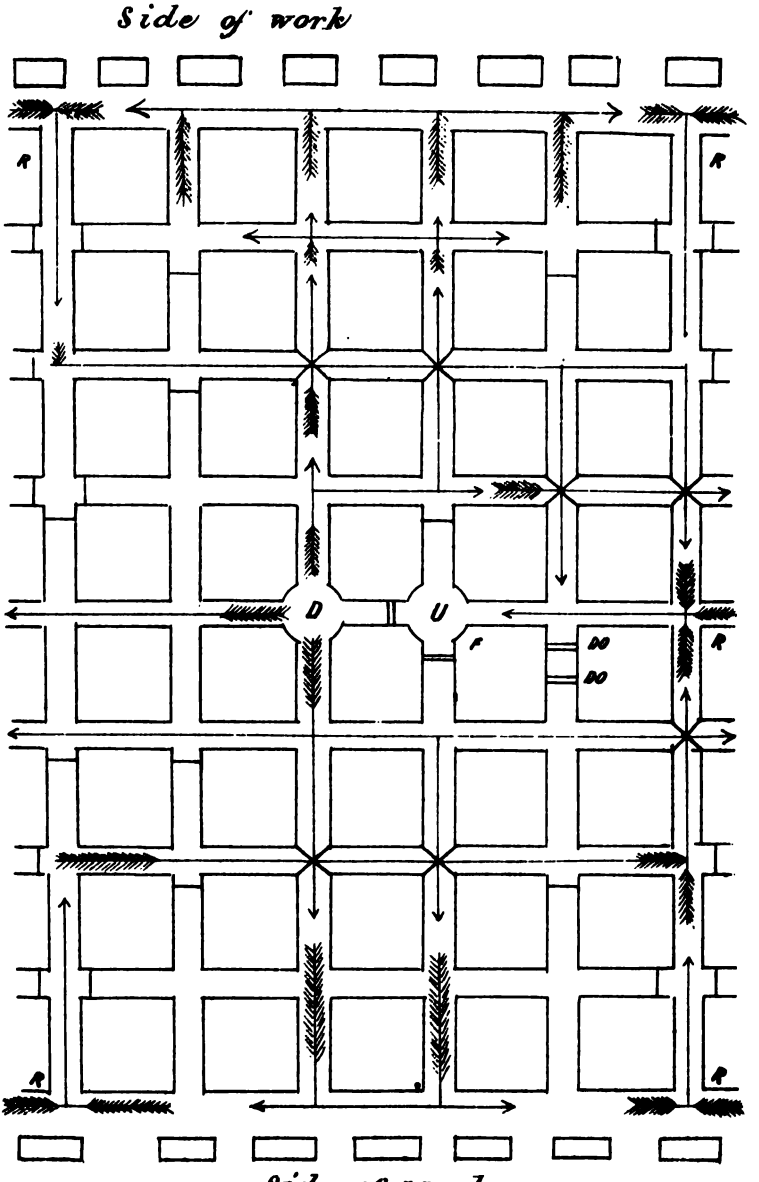


Fig 19 Working Home

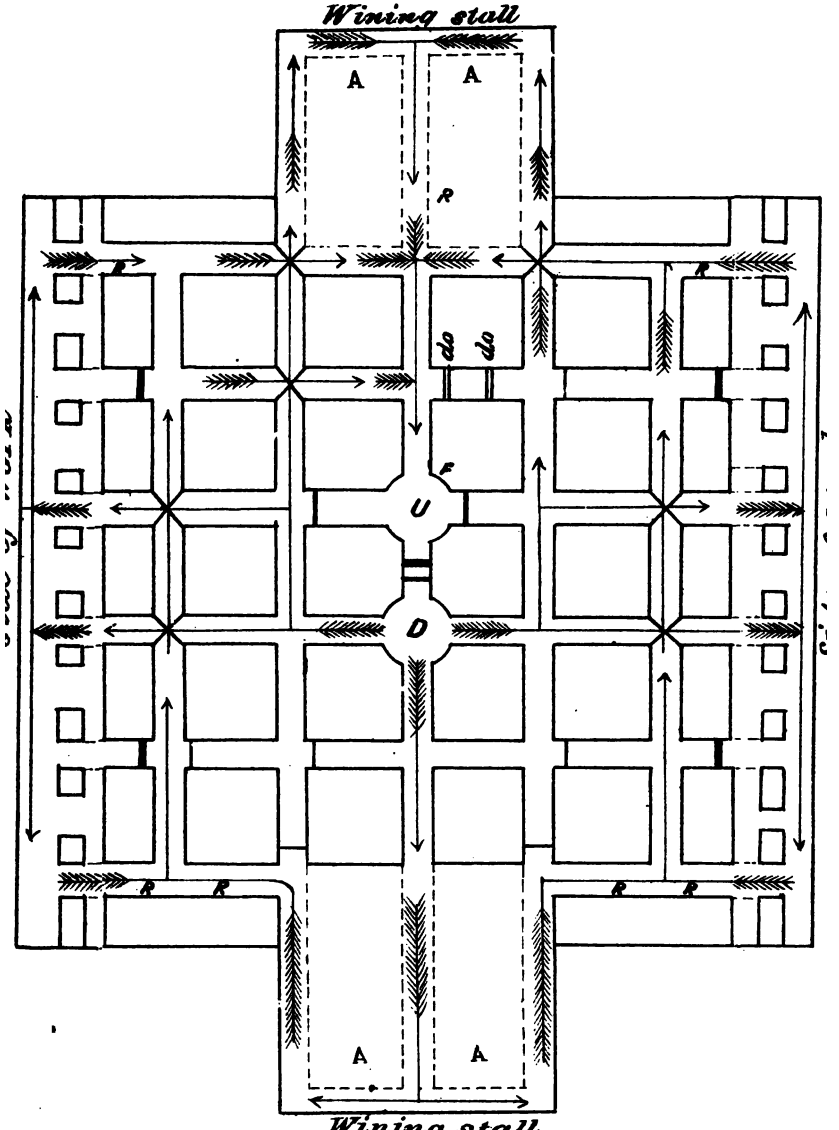


Fig 20

Working from Home

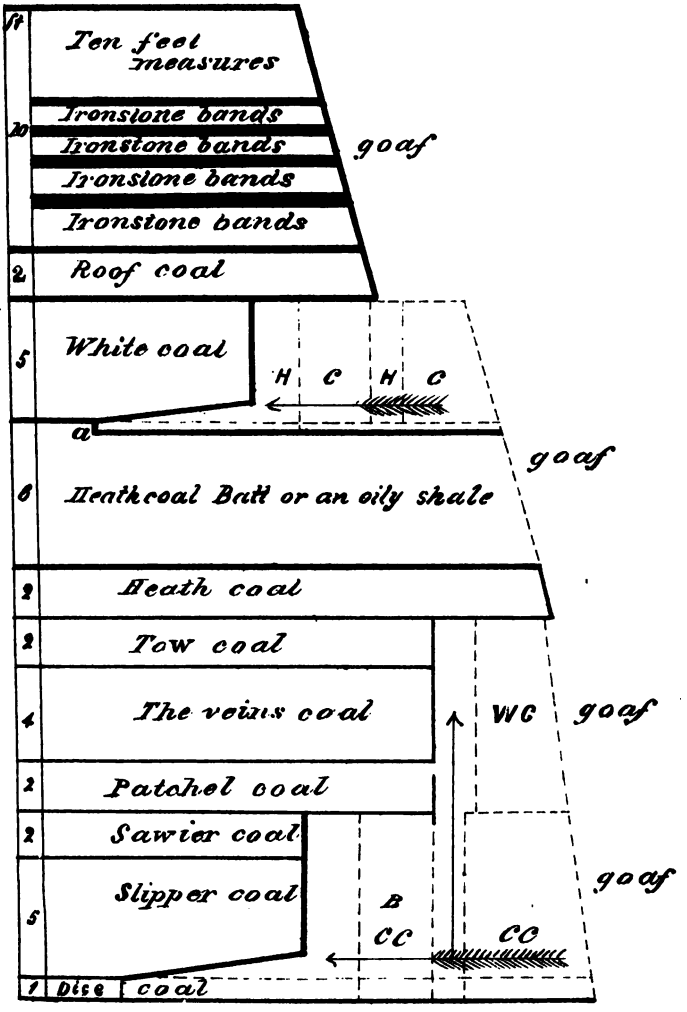


Fig 21

End View of a thick coal stall

THEODOLITE

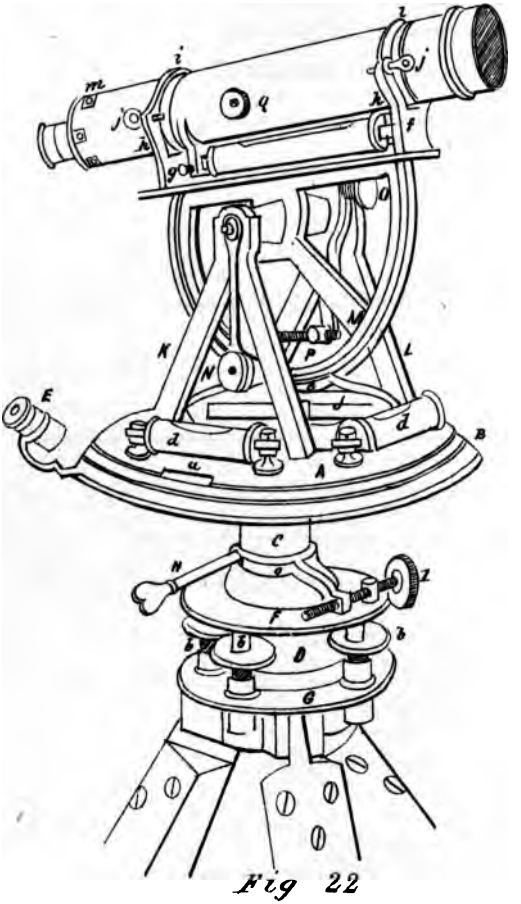


Fig 22

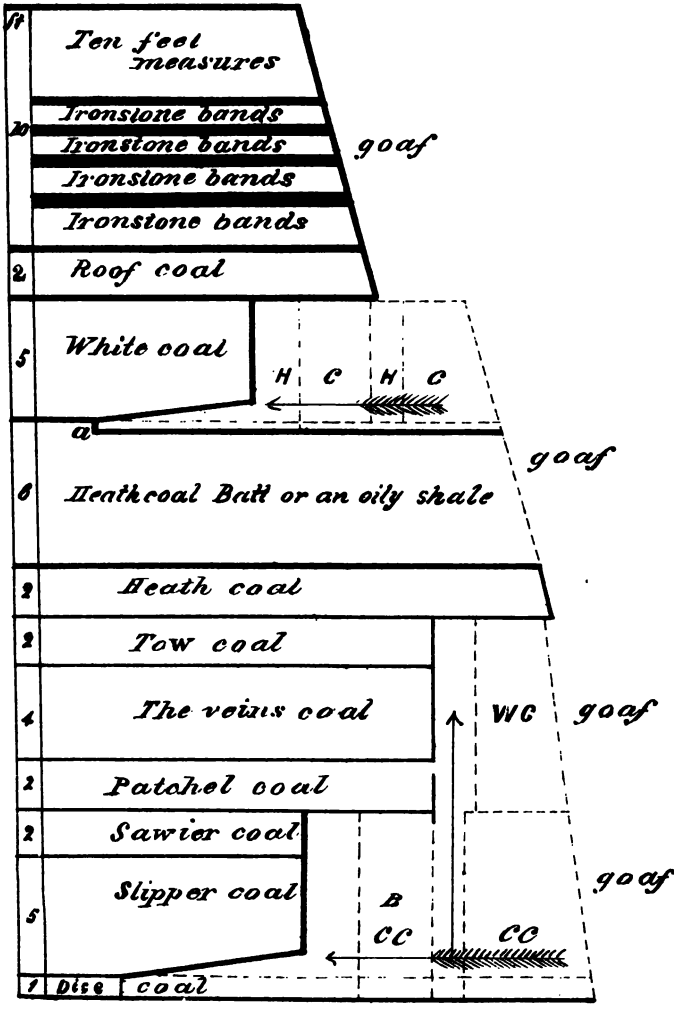


Fig 21

End View of a thick coal stall

ERRATA.

Page	1,		line 20,	for	"irregulary" read "irregular."
„	7,	par. 13,	„ 5,	„	"34 ÷ 14" read "34 × 12 ÷ 14."
„	8,	„ 13,	„ 8 & 10,	„	"4908" read ".4908."
„	9,	„ 17,	„ 6,	„	"bend at O" read "at C."
„	9,	„ 17,	„ 9,	„	"cup at O" read "cup at C."
„	9,	„ 17,	„ 10,	„	"then at C " read "then at B."
„	9,	„ 17,	„ 11,	„	"A and C " read "A and B."
„	19,	„ 43,	„ 5,	„	"geunao" read "gennao."
„	23,	„ 58,	„ 2,	„	"15.0" read "15 deg."
„	23,	„ 58,	„ 8,	„	"104 deg. F. below zero" read "—40 C."
„	23,	„ 58,	„ 11,	„	"167 deg. F." read "—75 deg. C."
„	24,	„ 63,	„ 6,	„	"21.105" read "1.105."
„	29,	„ 82,	„ 3,	„	"hydric sulphride" read "hydric sulphide."
„	35,	„ 104,	„ 13,	„	leave out "and" the second word.
„	36,	„ 114,	„ 3,	„	"spring" read "spongy."
„	39,	„ 123,	„ 6,	„	"calicum" read "calcium."
„	40,	„ 128,	„ 12,	„	"if found" read "is found."
„	42,	„ 132,	„ 3,	„	"cooking" read "coking."
„	42,	„ 133,	„ 6,	„	"calice" read "calcic."
„	43,	„ 135,	„ 8,	„	"permenian" read "permian."
„	43,	„ 136,	„ 9,	„	"calium" read "calcium."
„	44,	„ 136,	„ 1,	„	"calice carbonate" read "calcic carbonate."
„	44,	„ 136,	„ 3,	„	"Liassie, Pernian" read "Liasic, Permian."
„	44,	„ 137,	„ 5,	„	"dalomite" read "dolomite."
„	44,	„ 138,	„ 5,	„	"chemical work" read "chemical works."
„	82,	„ 205,	„ 11,	„	"shorting" read "thorling."
„	84,	„ 207,	„ 7,	„	"(Fe2 O2)" read "(Fe2 O3.)"
„	84,	„ 207,	„ 15,	„	"anhydrans" read "anhydrous."

Chemistry of the Mine.

INTRODUCTION.

The earth is a planet of 7,926 miles in diameter with a superficial area of 125,642,900 squares miles—two-thirds of which are covered with water. It moves at the rate of 65,000 miles an hour—in perfect harmony with eight primary and about 100 secondary planets around the sun (the centre of the solar system) at a mean distance of 95,000,000 of miles, and its solar light is supplied by that luminary. Its entire volume is estimated at 1,256,195,670,000,000,000,000,000 tons (1 quadrillion 256 thousand 195 trillions 670 thousand billions of tons).

The earth is not a perfect sphere—but approaches so near to that figure that it is called a spheroid, and its structure may be graphically defined as consisting of rocks, minerals, and soil.

Its rocks are divided into two distinct sections—as "Igneous" and "Aqueous" rocks. Igneous rocks appear to have been subjected to the action of internal heat, and at some period of the earth's history, must have been in a state of fusion, as they are generally of a crystalline structure of very irregulary forms, and are entirely destitute or void of stratification. Aqueous rocks are formed by regular accumulations of sedimentary depositions of fine powdered matter at the bottom of rivers, lakes and seas, which have been handed over to the aqueous fluid by a combination of

We may hear the sound of a gush of wind forcing an entrance into our rooms through the crevices of the window or the keyhole of the door, and can feel its effects most sensibly on a cold frosty morning at the extremities of our hands and feet.

4. Such is the adaptation of the atmosphere to human requirements that we can see not only objects that are moving within a given radius from our centre, but, with distinct precision, through a pure atmosphere, can view objects 100 miles distant on the earth, and, without the aid of a glass, can survey a large per-centage of planetary orbs or heavenly bodies.

5. In consequence of the high flexibility of the atmosphere we can move from place to place without any apparent resistance or inconvenience from it, notwithstanding we have individually to support a volume of this transparent fluid pressing in every direction upon us to the enormous amount of 15 tons, or a mean pressure of 15 lbs. to the square inch of surface of our bodies. However great this pressure may seem to the superficial observer, it is not more than is necessary to suit the conditions of animal and vegetable life. Suppose, for the sake of argument, that the atmospheric pressure was reduced to one-half its present density, the result of this would be that our bodies would become bloated and swelled out to serious dimensions, while the vaporation of liquids would be increased to such an extent that the earth would be literally encased in a sea of mist, thereby rendering the body incapable of action. But to continue our supposition, let us take an opposite view of the case: suppose the atmospheric pressure to be increased to 30 lbs. per square inch of surface, if the rays of light in their passage from the sun to the earth came in contact, through this dense column of air, with the earth's inhabitants, the whole human family would speedily die of inflammation of the lungs; notwithstanding this, it has been proved that a man can work, without any apparent inconvenience, under a pressure of three atmospheres or

45 lbs. per square inch, so long as the sun's rays do not pass through it.

6. The density of air is fixed at 1.00, although it is neither the heaviest or the lightest of gaseous bodies, and is regarded by the chemist as the standard of comparison when treating on the specific gravities of gases and vapours. It is 810 times lighter than water and 11,000 times lighter than mercury; its density is not uniform throughout its entire volume, but rapidly diminishes as we recede from the earth's surface. Were its density uniform it would only extend to a distance of five miles from the earth, but owing to its varying condition its uppermost stratum or layer cannot be reached at a less distance than 45 miles from the earth's crust.

7. Variations of density. It is only a little over two centuries since the variation of atmospheric density was discovered, but such is the importance of this principle to the commercial world that by the aid of proper instruments, atmospheric changes can be easily detected and made known. A change of atmospheric density is indicative of either heat, frost, rain, or snow, and to the coal miner it sometimes means a principle which involves life or death. These changes are ascertained by means of an instrument known by the name of barometer.

8. Barometrical discovery. This useful instrument was discovered by an Italian gentleman, the name of Torricelli, successor to Galileo, as a professor in the University of Florence. He conceived an idea in his mind that the atmosphere, like other material substances, to some extent, was subject to certain physical conditions which did not appear directly to come within the range of optics; so that after matured reflection on the subject he had a glass tube made of given dimensions sealed at one end, and also a small trough. He filled the trough half full of mercury, and then filled the glass tube with the same liquid. On placing his

finger on the open end of the tube he plunged it into the mercurial trough, and on removing his finger he instantly perceived the mercury falling, and in a second or two it stopped and remained stationery. On measuring the mercurial column in the tube he found that the atmosphere sustained a column of mercury 30 inches in height. This enabled the philosopher to calculate the weight of the atmosphere, which was in a direct line with his instrument, so that the only thing required next to complete the experiment, and give certainty to every point involved in the discovery, was to ascertain whether the density of the air was uniform throughout its entire volume. To meet this requirement a young Frenchman, the name of Blasie Pascal, on hearing of Torricelli's successful experiment, was anxious to know whether the atmosphere would sustain the column of mercury the same height in the tube on the top of a high mountain that it had sustained in the lowlands of the district in which his friend Torricelli resided. Consequently, he wrote to his brother-in-law, M. Perier, who resided at Clermont, in Auvergne, a mountainous district of France, requesting him (after detailing to him full particulars) to repeat the experiment on the top of "Puy-de-dome," a mountain near Clermont, between 3,000 and 4,000 feet above the level of the sea. M. Perier undertook the experiment, and found that the mercury stood three inches higher in the tube at the bottom of the mountain than it did at the top, thus satisfying the craving anxiety of the young Frenchman, and unfolding a valuable discovery to the world, that the density of the atmosphere was not uniform throughout its entire volume (see fig. 1).

9. Torricelli's instrument, though somewhat rude in appearance, has proved to be of much more importance to the civilized world than its inventor at first imagined, and by slight modifications of its structural form, it is now the recognised instrument for testing the atmospheric changes or difference of atmospheric densities.

It is called "Barometer" from the Greek "Baros"—pressure or weight, and "metron," a measure.

10. From what has been said in the previous paragraphs, it must not be understood that the different degrees of variations of atmospheric density is due alone to the difference of altitudes; the different seasons of the year, combined with the varying degrees of temperature of heat and cold, play an important part in this respect. At the surface of the earth the density of the air is always greatest in hard, frosty weather, and is at its lowest density when blowing from the south, and fully saturated with moisture.

11. At the moderately warm temperature of 60 deg. fahrenheit a cubic foot of air weighs 547 grains, or 1.25 ounces, or 0.07825 lbs; at the temperature of 32 deg. it weighs 0.080728 lbs., under an even pressure of 14.7 lbs. per square inch; and one cubic foot of air at 32 deg. is equal to 1.367 cubic feet at 212 deg., which clearly proves beyond doubt that, regardless of altitude, the density of the air diminishes in proportion to the higher degrees of temperature to which it is subjected.

12. Water is 810 times heavier than air, and 14 times lighter than mercury; so that mercury is 11,000 times heavier than air, and is the substance used in the barometrical tube for testing the pressure of the atmosphere.

13. The weight of a cubic foot of water is 62.5 lbs.; if, therefore, the atmosphere will balance a column of water 34 feet high, it must be evident, that it will only balance a column of mercury in the barometer 29.136 inches, as $34 \div 14 = 29.136$ as before stated, and as one cubic inch of mercury weighs 0.4908 lbs., it must of necessity be regarded as the multiplier of barometrical calculations with respect to the density of the atmosphere, taking it at a mean pressure of 14.7 lbs. per square inch of surface; therefore, if the height of the mercury in the barometrical tube be multiplied by 0.4908, it will give the atmospheric pressure per square

inch, and that product, multiplied by 144, will show the pressure of air per square foot. The following examples will convey more clearly the principle to the understanding of the student thus:—What is the atmospheric pressure when the mercury is $28\frac{4}{10}$, $29\frac{3}{10}$, $30\frac{1}{5}$, and $30\frac{7}{10}$ inches respectively in the barometer? Here 1st, 28.4 × .4908=13.9 lbs. per square inch × 144= 2001.7 lbs. per square foot; 2nd, 29.3 × 4908 = 14.38 lbs. per square inch × 144 = 2070.78336 lbs. per square foot; 3rd, 30.2 × 4908 = 14.822 lbs. per square inch × 144 = 2034.391 lbs. per square foot; and 4th, 30.7 × .4908 = 15.06756 lbs. per square inch × 144= 2169.7284 lbs. per square foot.

14. The mechanical engineer, who has to construct a pumping apparatus to lift water from a given depth, takes advantage of the atmospheric pressure by making it in obedience to the law of gravity force his water up the pipe a given distance before the engine is permitted to touch it, thereby dispensing with a certain amount of mechanical force he would otherwise require.

15. The minimum pressure of the atmosphere is considered to support a column of water 33 feet high from its base of action, the engineer being fully alive to this fact fixes the clack of the working barrel 27 or 28 feet from the bottom of the pump-trees, and the air pressing down on the surface of the water in the well or sump, forces it up the pipes through the clack and thus hands it over to the engine. The engine has no sooner commenced its lifting stroke than the atmosphere again exerts its full power on the water as before, forcing it up the pipes after the bucket, so that at every stroke of the engine the atmosphere performs its share of the work.

16. The engineer is not always satisfied with the work the atmosphere performs in this respect, but at times, institutes an enquiry, in order to ascertain if an outlet can be found for his water within a reasonable distance from the well, having a fall of 34 feet from the summit of his column of water, thus balanced by the atmo-

spheric pressure 33 feet high. On finding the result of the inquiry to suit his purpose, he replaces his engine by a syphon, and thereby makes the atmosphere perform the duties of a forcing pump.

17. A syphon, as used for mining purposes, is made by coupling pipes together, the joints being made perfectly air-tight, the delivery limb being six inches longer than the other limb, each limb being supplied with a stop-cock or valve at AB, and a cup in the centre of the bend at O, through which the syphon is filled with water and the air properly excluded (see fig. 2). The syphon being filled with water a bonnet is screwed on to the cup at O; the valve or stop-cock is then opened at A, and then at C, when the water instantly begins to flow from the well D, through the limbs A and C, in obedience to the laws of specific gravity and atmospheric force.

ELASTICITY OF AIR.

18. The elasticity of the atmosphere, like most other material substances, is seen by the way it expands and contracts when subjected to pressure or to different degrees of heat or cold. The air is a highly elastic fluid, and in its ordinary condition is equal to 14.7 lbs. per square inch; this is regarded as its elastic force, and is the multiplier of all additional atmospheres with which it is united. The elastic spring of the air is in proportion to the pressure applied to it: if a cubic foot of air be put under a pressure of two atmospheres it will be compressed into half its former volume; if under a pressure of three atmospheres it will be reduced to one-third; and if under a pressure of four atmospheres it will only occupy one-fourth of the space it filled before it was compressed: but the moment it is released from the pressure it will spring out to its original dimensions. This is what is meant by the word elasticity.

19. The motion of the air to a great extent, if not entirely, depends upon its own elasticity, and its elastic

23. If all the water on the earth was at the same constant temperature as the water at the tropics—80 deg. Fahrenheit, the vapour would become visibly so dense that the whole world would be speedily immersed in an atmosphere of air and mist of such enormous proportions, that it would not only balance a column of mercury 60 inches high, but it would stop the process of vaporation and prevent liquids and solids from boiling. The reason for this is plain if we take into consideration the fact that, when the maximum capacity of the air for vapour had reached its ultimate limit, there could not be any farther admission within its confines, unless by some project of logic at present unknown to the word, the density of the atmosphere could be reduced, accompanied by a proportionate enlargement of its volume.

HEAT.

24. Heat—Regardless of the sun's rays, we have both light and heat at our command. Caloric, the principle or element of heat, is a fine subtle, invisible fluid which is diffused through the whole of nature; the sun itself possesses an equal share of it; indeed it is rare to find any two substances possessing the same specific quantity of caloric. It is generally believed in the scientfic world, and we are not aware that it has otherwise been disproved, "that heat is conveyed in vibrations of the ultimate particles of matter," which means that one particle of matter moves heat from itself to another particle, so as to diffuse a uniform measure of it through the entire volume; but as light travels through space at the rate of 25,000 miles in $\frac{1}{8}$ of a second of time, or 200,000 miles per second, it is difficult to reconcile velocity on this principle.

We have, however, artificial light every day by the union of hydrogen and carbon, assisted by the oxygen of the air in burning spirits and light oils; and the high temperature of the interior of the globe, with its

constant increase of one degree of heat for every 70 feet descent into the earth where the sun's rays cannot penetrate, in addition to volcanoes, is a proof, or at least presumptive evidence, that every class of material in the composition of our globe possesses caloric to a certain extent.

25. Heat is not a ponderable substance. It cannot be weighed. A solid is just as heavy when it is absolutely hot as when it is absolutely cold; but its effects, whether in the gaseous liquid or solid state, can be seen and fairly gauged when subjected to either chemical or mechanical experiments: thus, for instance, a gas expands in every direction proportionate to the degree of heat to which it is raised; water, under the same conditions of temperature, passes from a state of ice to vapour; whilst a bar of iron, similarly treated, becomes longer and thicker.

26. When heat enters a body, so as not to increase its temperature in reducing it from a solid to a liquid state, it is called latent or insensible heat; as in the case of reducing ice to water.

If a block of ice, a dish of water, and a dish of snow all of one uniform weight be placed in a room, and each subjected to the same degree of temperature, it must be evident that the ice and snow would each receive the same degree of heat as the water. Now on placing a thermometer in the water dish, and observing the height it rises to in one hour, the temperature of the room being kept uniform throughout the time it takes to melt the snow and ice, enables us to measure the exact amount of heat that has been absorbed or rendered latent in converting snow and ice into water: thus, for instance, if the thermometer rose six degrees in one hour, and the ice and snow were only melted in 12 hours, that fact would convey to our minds that 72 deg. of heat had been imparted to the snow and ice during their conversion, without the water being made sensibly warmer, for $12 \times 6 = 72$ deg.

27. When the thermometer is plunged into boiling water the mercury rises in the tube to 212 deg. Fahrenheit; if, however, the water be allowed to remain at the same temperature till it is all generated into steam, and the thermometer be plunged into it, it will stand as before—at 212 deg., notwithstanding the fact that 900 deg. of heat have been expended in its conversion from water to steam. Here, as in the former experiment, we have 720 deg of heat rendered latent by this transformation; for 180×5 deg.$-180 = 720$ deg.

The conversion of water into steam—an element of the utmost importance to the mechanical engineer—is attended by a gradual operation, that is to say, that it takes five times as long to generate water into steam than it does to raise the temperature of water from 32 deg. Fahrenheit (freezing point), to 212 deg. Fahrenheit (boiling point). If the vaporation was not gradual the whole of the time the water was rising in temperature, it would all burst into steam the moment it had acquired 180 deg. of heat. The mechanical genius would here find it hard work to cope with the enormous amount of force thus evoked instantaneously into action, as every cubic foot of water would produce 1694 cubic feet of steam—a force sufficient, with a very limited supply of water, to shatter the strongest boiler to pieces; hence, therefore, the steam is in reality hotter than the water at boiling point, but insensible to the instrument above 212 deg.; therefore the extra heat it contains must be regarded as latent or insensible heat, which enables the fluid to retain its identity even while surrounded by considerable volumes of air and water.

28. Heat is transferred from one portion of matter to another under three separate and distinct conditions:—1st by conduction, which points out the way and manner in which heat passes from one particle of matter to another in contact with it; 2nd by convection, which means the method of conveying heat by particles of matter raised in temperature and set in motion; and

3rd by radiation, which means the emission of heat by a body at rest and not in contact with the substance to which it communicates.

29. Conduction of Heat.—If a rod of iron be placed in the fire at one end, the other end will soon be made sensible of the heat conducted, from particle to particle, through the whole length of the bar.

30. Convection of Heat.—If a spirit lamp be placed under a glass vessel, filled nearly full of water, the heat will be conveyed to the water immediately over the flame of the lamp, and in a short time a complete current of hot water will be rising in the centre, toward the surface, and returning again to the source of heat by the sides of the vessel; this process of motion will continue till the whole of the water is boiled.

31. Radiation is one of the most important ways in which heat passes from one body to anothor. A hot body in cooling, besides losing heat by the conduction and convective action of solids and liquids near it, parts with, or radiates, heat from itself to other substances till its temperature is reduced to the same degree of heat as the heat contained in the substance with which it is associated.

THERMOMETER.

32. Temperature.—The thermometer is an instrument for measuring heat and the temperature of the atmosphere, as well as the degree of heat contained in liquids and solids is gauged by it. The instrument shows the intensity of heat by the amount of expansion that takes place with the substance contained in the tube. There are four or five different kinds of thermometers, but those we shall refer to (the Fahrenheit and Centigrade thermometers) are constructed for the use of a liquid in the tube, as gases are considered to expand too much, while the solids expand too little. The liquid thermometers are charged with spirit of wine or alcohol and quicksilver. The former is intended to measure low

temperatures, as the spirit cannot be congealed by any known degree of cold; but it is not suited for high temperatures, as it boils at 141 deg. centigrade. The mercurial thermometer, however, freezes at 39 deg. below zero, and boils at 570 deg. above the freezing point, or at 602 deg. Fahrenheit.

33. The Fahrenheit thermometer is divided into 180 equal parts between the boiling and freezing points—the freezing point is marked 32 deg., and the boiling point 212 deg. The centigrade thermometer is divided into 100 equal parts between the boiling and freezing points, and is marked at the freezing point by an O, meaning zero, or the freezing point. The mercury and spirit rise in the tube proportionate to the degree of extra heat with which they are brought in contact, and fall in the same order, proportionate to the reduction of heat that takes place in these substances with which they are associated (see fig. 3).

34. The difference between the readings of the Fahrenheit and centigrade thermometers are reduced to equal measures by multiplying the degrees of heat of the centigrade scale by 9, dividing that product by 5, and adding 32 to the quotient, thus—$100 \times 9 \div 5 + 32 = 212$ deg. Fahrenheit. Or by subtracting 32 deg. from the Fahrenheit scale, then multiplying the remainder by 5, and dividing that product by 9, thus—$212 - 32 \times 5 \div 9 = 100$ deg. centigrade.

35. It must not be understood that the thermometer records the full or entire amount of heat of any substance to which it is applied; if, for instance, the instrument be plunged into a tank containing 100 gallons of boiling water, the mercury will rise in the tube until it reaches 212 deg. Fahrenheit, or the spirit reach 100 deg. centigrade, at which point they will become stationary; if they now be plunged into a vessel containing one gallon of boiling water, they will rise to the same maximum point—212 deg. Fahrenheit, and 100 deg. centigrade—respectively, which clearly proves that the

instrument only measures the intensity of the heat, and not the entire volume contained in any substance, as the former contained one hundred times the quantity of heat as the latter.

36. Hitherto we have confined our remarks exclusively to the properties of the atmosphere without instituting an inquiry into the principle as to whether it be a simple element or a compound substance. Every material substance, whether in gaseous, liquid, or solid state, lies within the confines of those two points; they must either be simple or compound.

The whole of our globe, with its water and atmosphere, is made up of some 63 elements. An element cannot suffer resolution into a simpler form than that in which it exists; a compound, however, by analysis, is reduced to its simple ingredients, which defines the nature and extent of each in forming the compound.

37. From the foregoing remarks we have now to consider whether the atmosphere is a simple element or a compound substance. The atmosphere was regarded by our fore-fathers at an early period of the world's history as "spirit distinguishing it from the more coarsely material substances with which they were better acquainted."—(Spiritus, air or breath.) By the able researches of the chemist the atmosphere is shewn to consist of more than one element, and therefore is a compound substance.

38. If we pour a small quantity of the methylated spirit of alcohol into a metallic cup, and place it in a dish plate half filled with water, on igniting the spirit, and placing a glass column or jar full of air over it with its open end immersed in the water, the carbon and hydrogen of the spirit will unite with the oxygen of the air in the jar, to form carbonic dioxide and water, whilst the water in the plate will rise up into the jar to occupy the space made vacant by the absence of the oxygen, and the nitrogen of the atmosphere in the vessel will ascend to the summit of the column before the rising

water which is pressing upward, to restore the equilibrium that had been destroyed. The same result may be obtained by burning a piece of phosphorus in the cup instead of the alcohol; but in consequence, however, of the white fumes from the burning phosphorus (phosphoric pentoxide) filling the jar it requires a little more time to see the result of the experiment in the latter than it does in the former process. The water in each case should rise up into the jar till it fills or occupys one-fifth part of its capacity. (See Fig. 4.)

39. The composition of the atmosphere as defined by the highest intelligence of the age is as follows, namely—In 100 parts of air there are 20.6 of oxygen, 77.9 of nitrogen, 1.46 of aqueous vapour, 0.04 of carbonic dioxide, accompanied by slight traces of ammonia, and it is characterized by its two principle constituents as four-fifths of nitrogen and one-fifth of oxygen, or in 10,000 parts of air we have 2060 of oxygen, 7790 of nitrogen, 4 of carbonic dioxide, and 146 of aqueous vapour (water).

40. The atmosphere is not a chemical compound, but a mechanical mixture of several gases, in 100 parts by weight of dry air there are 77 by weight of nitrogen and 23 by weight of oxygen; if the air therefore was a chemical compound it would be either a multiple of 14, the atomic weight of the nitrogen, or of 16 the atomic weight of the oxygen; but it is not a multiple of either, in consequence of which it is considered to be simply a mechanical mixture, owing to the following circumstances which always accompany the experiments made on this subject, namely—(1) the amount of oxygen and nitrogen in it are not such as the law of multiple proportion requires, and are not absolutely invariable; (2) when nitrogen and oxygen are mixed in the proportions in which they form air, no heat is produced, which always accompany chemical action, and (3) air can be separated into its constituents by such mechanical means as solution, as in the case of gunpowder.

41. The constituents of the atmosphere differ widely from each other, none of which can support animal life for any great length of time if breathed alone, but when combined in the proportions in which they stand related to that fluid, they produce the most beneficial results.

OXYGEN.

42. Oxygen at all observed temperatures when uncombined is a colourless, tasteless, and inodourless gas, and is the most widely diffused body in nature; it forms one-fifth part of the atmosphere by volume, eight-nineths of water by weight, is a constituent of nearly all the rocks and earths of the globe; it forms more than one-half of living plants and animals, and it is estimated to form nearly one-half of our planet.

43. It was first discovered by Dr. Priestley, from the redoxide of Mercury, in 1774, and was named by him "Dephlogesticated Air," (the supposed principle of inflammability.) Its name is derived from the two Greek words, "Oxys," acid, and "Geunao,"—I call into being—which signifies the acid producer.

44. Its symbol is O, atomic weight 16, molecule O2=32, density=(air being 1.00) 1.105, and is the only constituent of the air that supports combustion; but if breathed alone for a short time, the patient would be literally drenched in sweat in consequence of the rapid combustion that would take place in the system. When diluted, however, with four-fifths of its own volume of nitrogen, it is then, in the highest sense, just what the system requires to keep it in a healthy state of action.

45. The gas can be made from oxide of mercury, and as it constitutes 8-9ths of water, it can be obtained from the decomposition of that fluid by electrolyses, but it is generally prepared from Potassic Chlorate, a substance largely used in the Arts, and therefore easily obtained.

46. The general way of making and collecting the gas is to place a few crystals of Potassic Chlorate with

about one-third its volume of Black Oxide of manganese, or the red oxide of iron in a retort, and on applying the flame of a spirit lamp to it, the salt quickly melts and becomes a pure liquid, although free from water. The jars or bottles to be filled with the gas must be filled with water first, and set on the shelf of the Pneumatic trough with their mouths downwards, each of them in turn are set on the stool where it is filled with gas, and then slid off the stool on to the shelf. This process is continued till the whole of the gas is collected that is given off, and that is intended for experiments. (See Fig. 5.)

Many beautiful and very interesting experiments can be made with this gas. If you plunge a small splinter of wood with one end red hot into a jar of the gas, it will burst into full flame at once. By extinguishing the flame so as to retain the match red hot, the experiment may be repeated for a number of times; or by placing a small piece of phosphorus about the size of a pea, well dried by pressing it lightly between two sheets of blotting paper into a wire cup, after being lighted and emerged into the gas jar, the flame will become so intense that it is almost too much for the eye to bear. (See Fig. 6.) The most interesting experiment on combustion in oxygen is that with iron wire. A piece of the finest iron wire, such as is sold under the name of harpsichord wire, is formed into a spiral as large in diameter as the neck of the jar will allow to enter easily. One end of the wire is pressed into the cork of the jar, and the other end is heated and plunged into the flowers of sulphur, when a small portion of the latter adheres to it. By passing the wire into the jar and then pressing the cork lightly down in the neck of it, the sulphur bursts into a bright flame and kindles the iron wire, which in its turn burns and evolves a brilliant light—emitting white drops of fused oxide of iron, which fall into the water in the dish below. (See Fig. 7.)

47. From what has already been said with regard to oxygen, it will be seen that it is the only element in the

atmosphere that supports combustion, so that animal life depends entirely on it, in consequence of which the atmosphere in its ordinary condition of purity should be maintained in the mine under all circumstances regardless of cost.

NITROGEN—OR AZOTE.

48. Nitrogen is widely distributed in nature. It forms four-fifths, or 79 per cent. of air by volume, is present in the native nitrates, in coal and other minerals, and is a constant ingredient of plants and animals. Its name signifies the nitre producer. Its symbol is N., atomic weight 14, molecule $N2=28$, density 0.971. This gas was discovered by Dr. Rutherford in the year 1772, and is named from the Greek words A. and Zoe—Azote or Azotic gas.

49. Nitrogen has neither taste, colour, or odour, and does not exert an influence on colouring matter. It neither burns nor supports combustion, cannot maintain animal respiration, and is therefore void of positive properties to a great extent.

50. Nitrogen when uncombined is a negative substance, but when combined, it forms compounds which are possessed of marked properties, such for instance as hydric nitrate, ammonia, etc.

51. The best and cheapest way of preparing it is to deprive the atmosphere of the oxygen it contains, and thereby allow its nitrogen, which forms four-fifths of the air, to go free. (See Fig. 4.)

If great purity of the gas is required, the phosphorus, which consumes the whole of the oxygen should be used instead of the alcohol.

52. Although the gas is void of positive properties and cannot support combustion, it is of the utmost importance as a constituent of the atmosphere, in moderating the strength of the oxygen, which could not be breathed alone for any great length of time.

CARBONIC DIOXIDE.

53. Carbonic dioxide, or carbonic acid gas, is a compound formed by the union or chemical action of carbon and oxygen. Symbol Co. 2; atomic weight, 44; density, 1.53. The gas is found in all natural waters, it is a product of the combustion of fuel, and a large quantity of it is evolved by volcanoes. Decaying vegetables give off the gas rapidly during darkness, and it is a constant product of animal respiration.

54. Carbonic dioxide is a poisonous gas, and endangers life when the air contains 8 per cent. of it, and when it constitutes one-tenth of the air it extinguishes lights, but when the atmosphere is in its normal condition of purity it contains about the one-2,500th part of its own volume of the gas. It is a little over $1\frac{1}{2}$ times the weight of air, and in consequence of its great weight it is always to be found near the floor of the mine.

55. Preparation of the gas.—The gas is generally prepared from calcic carbonate in the following order: Place about $1\frac{1}{2}$ oz. of calcic carbonate (lime well broken up) into a small wide-mouthed bottle, and perforate or pierce two holes in the bung or cork, one to admit the funnel tube through which the acid, hydric chloride, must be supplied (in small quantities) to the carbonate, and the other to admit a small bent tube to conduct the gas from the bottle to the jar that is been given off by the chemical action (see Fig. 8), and in consequence of its great specific gravity, the gas can be poured out of one vessel into another like water. If the student will place a small piece of candle in an empty jar, and then pour a portion of the gas into it, the light will be at once extinguished, which will show its effect on animal life when brought in contact with it.

AMMONIA.

56. The ammonia of the atmosphere exists in that

fluid as ammonic carbonate. Its exact percentage in the air has not been clearly defined, but it is considered to form about the 1,000,000th part of its volume. Its symbol is H 3 N; atomic weight, 17; density, 0.59, or a little more than one-half the density of air.

57 Ammonia is largely distributed through nature, and occurs native in volcanic districts. It is a constant ingredient in rich soils. Clayey soils absorb it as ammonia chloride, and it exists in manures and other animal excretions. In the manufacture of coal gas, ammonia is given off as a product of the chemical action which takes place between the nitrogen and hydrogen of the coal, and it is present in the bones of animals.

58. Ammonia has a great affinity for water. Water at 15.0 can dissolve 700 times its own volume of the gas.

If a bottle be filled with the gas and opened under the surface of water which previously has been coloured with infusion of cabbage, the water will rush into it with violence, changing its colour from purple to green in its ascent, and with regard to its general properties, it can be liquified either by reducing its temperature to 104 deg. Fahrenheit below zero, or by putting it under a pressure of seven atmospheres = 105lbs. per sq. inch, and it will crystallize, if its temperature is reduced to 167 deg. Fahrenheit.

59. Preparation of the gas.—Reduce $\frac{1}{2}$oz. of sal-ammoniac to a powder, and mix with it about its own weight of quick lime; heat them in a retort or flask which is fitted up with a bent tube (as seen in Fig. 9), when ammonia in the state of gas will be given off, which can be collected by placing an empty bottle in a retort stand, and passing the other end of the tube into it as illustrated in the diagram; the gas being lighter than air ascends through it to occupy the highest part of the vessel, and in doing so displaces the air until it fills the entire capacity of the vessel. It can be collected over mercury, but it is not necessary to do so, and in consequence of its great affinity for water, it cannot be collected over that fluid.

60. Ammonia, like carbonic dioxide, cannot under any circumstances improve the condition of the atmosphere, and they must be regarded more in the light of appendages which are detrimental to the healthy operations of that fluid than otherwise.

61. The presence of ammonia in the air is easily known by its characteristic odour of hartshorn in either snow or rain water, which has been placed alongside of quicklime for a few hours. In consequence of its effects on colouring matter, it can be usefully applied in removing stains from cloths, and it is sold by the chemist as smelling salts, when it assumes the crystaline form.

DIFFUSION OF GASES.

62. Nothing can be more interesting and instructive to the mind of the patient enquirer into scientific truths than the law of gaseous diffusion. The student may well pause and enquire why the gases which constitute the atmosphere do not arrange themselves in layers, or stratify according to their respective weights or specific gravities, like other material substances in the universe. If three liquids are placed in a bottle, say mercury, water and oil, they will adjust their stratum in accordance with their specific gravities. With the mercury at the bottom, the water in the centre, and the oil floating at the surface, forms the third stratum.

63. If the gases of the atmosphere were governed by the law of specific gravity, we should have the poisonous gas carbonic dioxide resting on the earth. Its specific gravity being 1.529, air being 1.00; the oxygen, the hasty and eager supporter of combustion forming the second stratum, its specific gravity being 21.105, and the nitrogen, the moderating guard of the oxygen, forming the upper stratum far beyond the reach of animal life—its specific gravity being 0.972.

64. Had the gases of the atmosphere been governed by the law of gravity exclusively, with their arrange-

ments in the order as set forth in 63, this would have been a complete bar to the development of animal and vegetable life.

65. The gases composing the atmosphere, however, instead of stratifying like minerals or solids and liquids, intermix uniformly through each other in the proportions as already stated in 39 and 40; and such is the exact order of the combination that it contains the same proportions in every quarter of the globe, from the bottom of the lowest mine to the highest altitude traversed by man.

66. As soon as a gas is liberated from its confines, it would seem as if it were under the influence of the law of specific gravity, and in obedience to it, sought to adjust its stratification with the air according to its specific weight.

67. If a volume of carbonic dioxide (Co. 2=44, be liberated from a cavity, it will roll down to the lowest part of the surface in its immediate locality; and on the same principle if a volume of methylic hydride (H 4c=16) be liberated from a similar cavity, it at once ascends through the volume of air and spreads itself out in a thin layer at the summit of the room or chamber to which it escapes. But neither the heavy nor the light gas remain stationery; for while in the very act of changing their position by the law of diffusion, they assimilate themselves with the atmosphere in such a way, that, where the quantity is not so large as to destroy the properties of the air, the poisonous nature of the one, and the inflammability of the other, is diluted by the air and rendered harmless.

68. The diffusion of gases is inversely as the square root of their density; thus four measures of hydrogen (H—1) will diffuse itself through a volume of oxygen (0—16), whilst under the same conditions only one measure of oxygen will diffuse itself through a volume of hydrogen; or in other words four volumes of H will assimilate with the oxygen for every volume of O that

will assimilate itself with the hydrogen; hence therefore, the diffusion property of the two gases are as 4 is to 1, as the square root of 16=4 and the square root of 1=1.

69. If a piece of blotting paper three inches square be moistened with a solution of turmeric (Indian saffron), and laid on a clean plate or dish, covered with a deflagrating jar and a bottle of ammonia, be coupled with it as seen in Fig. 10, in a short time the ammonia, which is only a little over half the density of the air, will descend through the column in direct opposition to the law of specific gravity, and turn the turmeric paper from yellow to brown.

70. If two bottles both one size be filled, one with hydrogen and the other with carbonic-dioxide gas, and the latter which is 22 times heavier than the former, be set on the table, and the lighter gas bottle be coupled to it by means of a glass tube which passes through the cork of each vessel (as seen in Fig. 11), the gases will change vessels in the proportion of 4.6 of the light hydrogen to 1 of the heavy carbonic acid. To complete the experiment, and prove that the gases have diffused themselves through each bottle, contrary to the law of gravity, if a solution of lime water be poured into the hydrogen bottle immediately after their separation, the water will at once assume a cream colour, which shows the presence of the heavy gas.

71. If a glass tube open at each end, 20 inch long and 1 inch diameter, be sealed at one end by a thin paste of stucco (plaster of Paris), and filled with hydrogen gas by means of displacement, the gas being 14.7 times lighter than air, is set in a glass dish which contains a little clean water, with its open end immersed in the fluid. A small piece of oil cloth being now removed from the sealed end of the tube, which was to prevent the escape of the gas during the preparation, the hydrogen gas immediately begins to ascend through the stucco into the air, and the air in like manner descends through the stucco into the tube, assimilating themselves with

each other. This interchange of the fluids continues, with the escape of 3.84 measures of H from the tube for every volume or measure of air that enters it, until the proportions of air and gas in the tube can no longer be influenced by the law of diffusion. During the whole process the water in the dish is gradually rising up the tube in obedience to the law of gravity, to occupy the space made vacant by the extra escape of the hydrogen, which gives the most perfect and complete illustration of the law of gaseous diffusion. (See Fig. 12.)

72. From what has been said here on the subject of diffusion with the gases of the atmosphere, the same law holds equally good with all the other gases; and however strange it may appear to the superficial observer, to see a heavy gas rise up through a lighter gas, whose specific gravity may be double, or treble, or even twenty times lighter than its own, is a fact, so clearly demonstrated that there cannot remain the slightest doubt on the subject.

73. There are other gases which find their way into the atmosphere in thickly populated districts, where iron and chemical manufactures are carried on, but as they do not effect the constitution of the air in general, we have excluded them from this part of our subject.

74. Having briefly considered the conditions and composition of the atmosphere, it will be now necessary to consider its adaptation to the requirements of animal life.

75. An adult person in a state of rest inspires and expires 15 times a minute; but when in a state of activity 30 times, and in some special cases as far as 35 times per minute; and at each inspiration he inhales 30 cubic inches of air, and exhales 75 per cent. or 22.5 cubic inches of vitiated air, 4.75 per cent. of which is the poisonous carbonic dioxide gas; so that the minimum quantity of pure air—air free from all deleterious ingredients—he requires per minute, is 900 cubic inches, and he exhales in that time 675 cubic inches of vitiated air, 32 cubic inches of which is the poisonous gas; but as

halo in the form of a tubular pyramid, and as the candle is raised up into the gas the blue halo gradually shades away, as the gas approaches the explosive point, into a cream colour; the moment, however, that this change is observed by the educated eye, that moment, unless the candle is lowered, the gas will ignite, when all the terrible effects of an explosion of fire damp may be witnessed.

87. It was in consequence of the inflammable nature of this gas in coal mines that gave rise to the researches of Sir Humphrey Davy and Mr George Stephenson, which resulted in the production of the safety lamp, and for which as a mark of distinction, Sir Humphrey was knighted by the King of the United Kingdom of Great Britain and Ireland.

The Stephenson lamp, commonly called the "Geordy" lamp, is in the opinion of all practical miners, considered to be equally as safe amongst gas as the Davy-lamp, and they consider that Mr. Stephenson was as much entitled to this mark of honour as Sir Humphrey was: 1st—Because both the gentlemen were engaged in the investigation of the principle at one and the same time, but unknown to each other; 2nd—Because they each succeeded in producing a lamp suited to the requirements of a fiery mine; and 3rd—Because the one lamp is equally as safe in all respects in the mine as the other.

88. Preparation of the gas:—The gas can be made by heating a mixture of 40 grains of sodic acetate, 40 grains potassic or sodic hydrate, and 60 grains of quick lime powder.

It requires a great heat to liquify the metals, but when ebulition takes place, the gas is given off rapidly and in great abundance. The gas should be collected over water at the pneumatic trough as shewn at Fig. 5. Care should be taken to have one of the best infusible glass flasks for this experiment to prevent a breakage of the vessel, and no lighted candle or lamp should be placed near the gas.

89. Methylic-Hydride is void of colour, or invisible to the eye, without taste or smell, and will neither support combustion nor animal respiration, but when it is mixed with twice its volume of oxygen, or from 7 to 10 times its volume of air, it detonates powerfully.

It forms 35 per cent. of coal gas, and is the only inflammable gas in mines that is attended with great risk or danger of an explosion.

90. Ethylene.—Ethylene gas, like the methylic hydride, is a compound of carbon and hydrogen, and may be regarded as one of the "hydro-carbons." It forms 4.6 per cent. of coal gas, to which the coal gas is indebted for its great amount of luminosity.

Its original name was "Dutch liquid," but it is now commonly called "olifiant gas," from the fact that a mixture of the ethylene with chlorine gas unite to form a liquid thus:—If a jar half full of chlorine gas be filled up with "olefiant" gas, and placed on the shelf of the pneumatic trough, mouth downwards, in a few minutes the gases will unite, forming a liquid which is seen floating like drops of oil on the surface of the water, which gradually ascends up the jar as gas. This, therefore, illustrates the origin of the name "olefiant"—which is now known to the mine agent as "heavy carburetted hydrogen."

91. All gases below the standard density of air which is taken at 1.00 is classified as light gas, and those gases which exceed that standard are classified as heavy gas. Why the ethylene should be designated "heavy carburetted hydrogen" against the methylic-hydride "light," carburetted hydrogen is an exception to the law regulating gaseous fluids, seeing that both the gases are below the standard density of one.

92. Ethylene is not a natural product of nature. Its presence in coal gas is due to the decomposition of coal by heat in the retorts, where four measures of hydrogen unite with two measures of carbon to form the gas. This gas may be found in certain coal mines where large

quantities of fine coal dust are buried in the goaf. Under such circumstances the enormous pressure of the overlying measures would cause great heat to be emitted, in some instances to such an extent as to even fire the dust. Under such conditions olefiant gas would be given off to a limited extent.

93. Ethylene is a colourless or invisible gas. It does not support combustion or animal respiration. If breathed alone in its pure state for a few seconds the patient will die. It is a highly combustible gas, and burns with a clear light flame, producing during combustion carbonic dioxide and water from its combination with the oxygen of the air.

94. Preparation:—The gas can be made by mixing in a flask or retort ½ oz. of alcohol (rectified spirit of wine), with 1 oz. of strong hydric sulphate, a little sand should be added to the mixture to lessen its tendency to froth up toward the end of the action; heat is then applied by means of a spirit lamp, and in a short time the liquid evolves the ethylene with great rapidity, which should be collected over the pneumatic trough, as seen in Fig. 5. Its symbol is H 4. C 2; atomic weight, 28; density, 0.979.

95. The following experiments will illustrate the general properties of the gas:—1st. A small jar filled with the gas and kindled shows the brightness of its flame and the intensity of its luminosity. 2nd. If a strong thick jar filled one-fourth full of the gas and three-fourths full of oxygen be ignited, a powerful explosion occurs, accompanied by much heat, but little light. 3rd. If one measure of the gas be mixed with two measures of chlorine, on a light being applied to the mixture it burns with a smoky flame, and deposits soot in the jar, which is due to the chlorine uniting with the hydrogen and rejecting the carbon of the gas.

96. Carbonic-Dioxide (Co. 2). From what we have said with respect to this gas in our remarks on the atmosphere (53, 54, 55), it must be regarded as a

natural product of animal respiration, and the decomposition of animal and vegetable matter which is always going on in the mines.

97. There are few mines (if any) but yield "carbonic acid," or "black damp," as it is generally called, from the various measures contained in them, and of which its effects are most painfully manifested under certain conditions of atmospheric changes. When the wind is blowing from the south, south-east, or south-west, and saturated with moisture, it is no uncommon thing to find the gas protruding from the workings, the wastes and goaf of the mine in every direction, and at times to such an extent as to extinguish lights hundreds of yards back from the face work.

98. There are some mines which yield both the inflammable and uninflammable gases at one and the same time. This is a very common occurrence in certain districts in the midland counties. At the Monkwood Colliery in Derbyshire, the writer has seen the "light carburretted hydrogen fire in his lamp in one part of a stall, and the flame of the lamp extinguished in another part of the same stall by the black damp."

99. With regard to the production of this gas from the various sources of exhalation, the explosion of gunpowder, the chemical action of bodies or substances through internal heat, etc., proves beyond all doubt that the gas is a serious interruption to the ventilating current, and forcibly demonstrates the fact, that the ventilation of such mines must be sufficient to cope with the gases, if the property of the owners and the lives of the miners have to be protected.

100. Carbonic Oxide (Co.). This gas is not a natural product of the elements, although a compound of carbon and oxygen, but is formed by the action of heat which deprives carbonic-dioxide of half its oxygen, and thereby reduces it to a new compound—"Carbonic Oxide."

Its symbol is Co.; atomic weight, 28; density, 0.967; so that it is a shade lighter than common air.

101. The gas is void of colour, consequently invisible to the eye; it has no taste, but a slight odour; it neither supports combustion nor animal respiration. In consequence, however, of its combustibility, it burns with a beautiful blue flame, which may be seen almost daily, but especially in frosty weather behind the kitchen fire-grate, where the carbon of the fuel unites with the oxygen of the air that passes within the grates to form carbonic dioxide, and this gas in passing through the red hot cinders in its ascent for the chimney, is decomposed by the loss of half its oxygen, which forms the new element we call carbonic oxide.

102. Carbonic oxide is never found in a mine, except in a furnace drift or in some other part where a fire is kept burning at a red heat, or except in the explosion of gunpowder for blasting the minerals.

103. It was in consequence of the carbonic oxide gas passing from the furnace drift back over the furnace, that destroyed the lives of the 199 men and boys at the New Hartley Colliery in Northumberland, in January, 1862, who were entombed in the mine for several days, through the breaking of the beam of the pumping engine, one-half or 20 tons of which fell down the shaft, which was 100 fathoms deep, and blocked the pit above the furnace drift, thereby cutting off the intake and return air passage, and every possible chance of the men's escape to the surface.

104. Preparation of the gas:—Carbonic oxide can be made either—1st, by passing carbonic dioxide through red hot charcoal in its passage from the flask, where it parts with one-half its oxygen, and enters the jars at the pneumatic trough as carbonic oxide; or 2nd, place a few crystals of the deadly poison oxalic acid in a flask, and pour a small quantity of hydric-sulphate on them, after which apply the flame of a spirit lamp under the flask, when much heat is produced; the crystals melt, and the gas is given off rapidly in a mixed state, but by passing the gas in its passage from the flask through a

solution of potassic hydrate, which retains the carbonic dioxide and the gas, carbonic oxide enters the jars in a pure state. (See Fig. 13.)

The gas is a most deadly poison; $2\frac{1}{2}$ per cent. of it in the air endangers life.

105. Hydric-Sulphide (H2 S.) is a compound of sulphur and hydrogen, which is sometimes met with in coal mines. The gas is evolved from volcanoes, and occurs in solution in many mineral springs, which owe their offensive smell and taste to the presence of the gas. The decomposition of animal and vegetable matter which contain sulphur in solution (Iron Pyrites), and the general contents of common sewers, are sources from which the gas is produced.

106. Hydric-Sulphide is void of colour; it neither supports combustion nor animal respiration, but owing to its combustibility, it burns when exposed to a supply of air on being ignited.

107. Hydric-Sulphide is a much more poisonous gas than carbonic oxide; to breathe an atmosphere which contains one per cent. of it brings on fainting fits, and an atmosphere which contains two per cent. of the gas is fatal to life.

108. Water dissolves $2\frac{1}{2}$ times its own volume of the gas, and when it is given off in the mines it is in consequence of the decomposition of a substance which contains sulphur in solution, such for instance as Iron Pyrites (Fe. S2.), to which it is probable it owes its offensive smell of rotten eggs.

109. The gas is not easily detected by the aid of either lamp or candle, as the flame of neither of them is enlarged by its presence. Under such circumstances the miner should feel himself in positive danger the moment he perceives an odour resembling that of addled eggs.

110. Hydric-Sulphide in solution furnishes the chemist with a valuable test for the distinction of the metals and other bodies. If a jar of the gas be kindled, it will

burn with a blue flame and deposit sulphur within the vessel, and when mixed with 1½ times its own volume of oxygen and kindled, it burns with an explosive force, in which case the hydrogen of the gas is reduced to water, and its sulphur to sulphurous anhydride. When the gas is mixed with an equal volume of chlorine it is at once decomposed; its sulphur separates, and the chlorine combines with the hydrogen to form chloride. If a silver plate or coin, or a piece of paper soaked in a solution of plumbic acetate (sugar of lead), is placed in a jar containing the gas, they will be at once blackened or discoloured.

111. When a solution of the gas is required for test purposes, it is conducted through a series of wash bottles filled three-quarters full of pure water by means of glass tubes as seen in Fig. 14, and great care should be taken to have the surplus gas, if any, conducted from the test bottle into the open air, or better still, up a chimney.

112. Preparation of the gas:—Place ½ oz. of Ferrous Sulphide well broken up into a flask; add a little water to it; after which add a small quantity (by degrees only) of hydric sulphate, in the same way as in the preparation of hydrogen (Fig. 15).

113. Having briefly considered the five principal gases of the mine, it may not be out of place here to make a few observations on their radical bases or the two fundamental elements—Carbon and Hydrogen, which give rise to their formation.

HYDROGEN.

114. Hydrogen does not appear to exist uncombined on the earth; it is said to have been discovered in a soft spring substance, known by the name of "Meteorite," or a meteoric stone. The meteorite is supposed to have been dislodged as a fragment from the body, while in its flight through space, and falling through the atmosphere, reaches the earth pretty much in the form in

which it is found. Its symbol is H.; molecule, H2; atomic weight, 1; density, 0.0693.

115. Hydrogen is the lightest body in nature; it is 14½ times lighter than air, and 16 times lighter than oxygen. It is much used by plumbers and whitesmiths as a source of heat for soldering soft metal pipes, etc. In consequence of its great lightness, it is used by æronauts for balloons, which enables the philosopher to ascend into mid regions, where he forms a comparison of the air's composition, density, and temperature; there, with its composition, density, and temperature at the earth's surface, by which means a valuable amount of very important information is obtained. The health of the human race, to a very great extent, depends upon the state of atmospheric density, and the Medical Faculty finds it necessary at times to recommend their patients to a change of air, meaning of course, a change of atmospheric density, as the most likely means to restore their health.

The composition and temperature of the atmosphere as well as its density play such an important part on the health of the people, that it is only necessary to say, that on these three vital points, depends the entire vitality of the animal kingdom.

116. Hydrogen was discovered by Mr. Henry Cavendish, the father of Pneumatic Chemistry, in the latter part of the seventeenth century, and was named by him "Inflammable Air;" but at a latter period on finding that water was formed when the gas burnt in air, and that one-fifth part of this air volume had undergone a change from air to water—enabled him to perceive that water was the "oxide" of the gas, and therefore, the name inflammable air, did not properly represent the true character or nature of the element, in consequence of which he substituted two Greek words: "Udos"—water; "Gennao,"—to produce.

117. Hydrogen is a tasteless, inodourless and invisible gas; it neither supports combustion nor animal

respiration. If a candle is plunged up into a jar of the gas, it is at once extinguished, and if breathed alone for a few seconds, the patient will die, in consequence of the oxygen of the air being prevented from entering his lungs.

118. Hydrogen is a constituent of coal, and forms 45.6 per cent. of coal gas; it combines with carbon to form methylic hydride, the fire-damp of the mines; when mixed with oxygen or common air, it forms an explosive substance, and when ignited, the explosion is accompanied by a loud report; but when the gas is allowed to pass through a small orifice either into air or oxygen, it burns with a flickering pale blue flame. Its luminosity is very small, but it partly compensates for this defect by giving off great heat.

119. The gas unites with oxygen to form water (H2 O), and hydric proxide (H2 O2). The gas is slightly soluable in water, but it has never been liquified, although subjected to a pressure of 3000 atmospheres, or 45,000 lbs. per square inch of surface.

120. Preparation of the gas:—The simplest and cheapest way to prepare it is by electrolysis. If a galvanic current is passed through a column of pure water, the water will suffer resolution into its two constituent elements, Oxygen and Hydrogen; the former is given off at the positive, and the latter at the negative poles of the battery, and can be collected in bottles or jars at the pneumatic trough.

121. The gas is more generally prepared from zinc by the action of Hydric Sulphate (H2 S04.)—Place ½ oz. of granulated zinc, chemically pure, in a flask or bottle that is fitted with a perforated cork that will admit two glass tubes into the neck of the vessel as seen at Fig. 15, the one to conduct the gas from the flask to the jars on the shelf of the pneumatic trough, and the other through which Hydric Sulphate (sulphuric acid) is to be applied to the metal; the jars being all filled with water that are intended for the gas; the flask is filled about ¼ full

of water, and then 30 or 40 drops of strong acid is passed into the flask through the funnel tube, when the hydrogen will be almost immediately given off with effervescence. Great care must be taken not to add too much acid at once, and as the gas forms an explosive mixture with air, no lighted candle or lamp should be near the approaches during the process of its evolution.

122. If the gas is made from merchants' zinc, it should be passed through a solution of potash and argentic nitrate of silver, when the former will precipitate the arsenic, and the latter will arrest the hydric sulphate which escapes with the gas from the flask.

CARBON.

123. Carbon.—Carbon is one of the elements, and is largely distributed through the animal, vegetable, and mineral formation of the earth. It occurs in nature uncombined as the diamond and graphite, or plumbago, and when combined with oxygen, it forms carbonic dioxide; with oxygen and calicum it forms limestone; with hydrogen it forms coal, and with hydrogen, oxygen, and nitrogen, it forms animals and plants.

Its symbol is C; atomic weight, 12; density in the diamond, 3.3; and in graphite, 2.2.

124. The diamond in its purest form is crystallized carbon; it occurs in alluvial soils, from the disintegration of quartz-rocks, and is found crystallized in the octahedra and other forms which belongs to the regular system.

The diamond is the hardest substance known; it is cut and ground by its own dust, and in consequence of its high refractive power for light, and its great transparency, it is much valued as a gem.

125. Graphite is a substance largely employed in the manufacture of pencils, which are commonly called lead pencils, although no lead is contained in it; but it is frequently associated with iron, in which case the graphite is not pure, but the harder portions of the

metal command a certain commercial value, when the metal is found in its pure state; like the diamond it consists of pure carbon.

126. Carbon exists or appears in several allotropic forms, but in each form it retains its own identity, and in none does it stand to greater advantage in the commercial world than when it appears in the form of coal, limestone and charcoal.

127. Carbon, it has been said in 123, combines with hydrogen to form coal, of which it becomes the principal element in that substance, and in consequence of their intimate relations and chemical affinity in this form, we have two of the inflammable gases out of the five gases that are met with in the mines as the result, namely:—"light" and "heavy" "carburetted hydrogen."

128. Coal formation:—The full extent of the coal formation is not at present known, but much valuable information has been given through the Geological Survey of this and other countries on the subject, and it is quite probable that, by proper application of the principle, many valuable coal seams, as well as large unexplored coal fields, may yet be discovered.

Coal has already been found in this country at a depth of 400 fathoms from the surface, and it is quite possible that beds of coal may yet be found at a still greater depth. But when we consider the fact, that the unvariable temperature of a mine if found at a depth of about 70 feet from the surface, with an increase of heat of one degree for every 60 feet further descent, we may reasonably expect to find the temperature at such a depth on an average of 89 degs. Fahrenheit; therefore, under such circumstances the question may be raised, at what further depths from the surface can the miner endure a temperature say of 90 degs. and upwards in the performance of his duty in the mines?

129. Area of the British Coal Field:—The area of the British coal field is estimated by Mr. Hull, at 5431 square miles, and after making reasonable deductions

with regard to the estimated quantity of coal within the same area, he considers that the quantity of workable coal from 1861, is 79,000,000,000 tons. If, therefore, the annual production could be limited to 80,000,000 tons, according to this estimate our native coal supply would extend to a period of 900 years from that date.

130. General distribution of the coal measures:—When we consider the enormous extent of the coal fields in Europe, Asia, America, and Oceanica, which have been partly defined, we cannot fail to see, apart from other mineral substances in which the element "carbon" plays such an important part, the prodigious growth of timber in the primeval forest, of which the coal measures consist. Therefore, coal is a rock, composed principally of carbon, with varying percentages of hydrogen, nitrogen, oxygen, and earthy substances (which forms the ash), deposited in the form of vegetable matter, which have undergone considerable physical and chemical changes.

131. Formation of the coal measures:—It is not our intention here, to discuss the geological history of the carboniferous formation, but it may not be altogether out of place to say, that the formation of coal from turf, peat, and timber, is due to a succession of their accumulations, which were subsequently imprisoned by the sedimentary formation, which overlie the coal measures, in consequence of which the accumulated mass thus imprisoned under great pressure was gradually squeezed closer and closer together; under such circumstances, the water contained in the vegetable matter was raised in temperature in proportion to the heat generated, and thus distributed through the entire mass enclosed, so that by the process of vaporation and chemical action, aided by the enormous pressure of the overlying strata, the vegetable matter was converted into a consolidated state, which is now known to the civilized world by the name of coal.

132. Classification of the coal measures: The coal

measures are classified as bituminous and non-bituminous coal, and may be arranged in the following order:—

Bituminous.—1st, cooking or coke-making coal; 2nd, chorry, or soft coal, which is well adapted for domestic purposes; 3rd, splint, or hard coal, which is more suited for steam and lime burning; and 4th, cannel, or parret coal, which is best adapted for gas-making.

Tarbarnite, although not of the coal measures, is nevertheless a member of the carboniferous group, and when found in a pure state, it will yield as much as 16,000 feet of gas per ton. The non-bituminous coal consists—1st, of anthracite, a dark close compact carboniferous rock, which contains about 90 per cent. of carbon, three per cent of hydrogen, and seven per cent. of earthy matter. In consequence of its high carboniferous constitution, it burns without smoke or flame, but gives out great heat, and is a valuable substitute for coke in smelting iron ores and drying malt, but it requires to be supplied with a good draught of pure air; and 2nd, lignite, which is a common coarse brown coal; it burns feebly, and gives out little heat; in fact, it is an inferior mineralized carboniferous substance of little or no importance either for domestic or manufacturing purposes, and the nearer it is found to the surface the more inferior is its burning quality. The chief difference between the bituminous and non-bituminous coal is in consequence of the former containing a greater quantity of hydrogen in its composition than the latter. The entire series in the order of their formation stand thus—1st, turf; 2nd, peat; 3rd, fossilwood, or lignite; 4th, common coal, of which there are many varieties; 5th, anthracite; 6th, graphite; and 7th, diamond.

133. Limestone formation:—The limestone beds, or calcareous rocks, which appear at the surface in different forms, are the result of the decomposition and successive accumulations of animal matter at the bottom of seas, which extends out in every direction from the embryo to the summit of the calice group, and which must be

regarded as representing a large per centage of the shelled animals that lived during the period of its formation.

134. The principal animals which have contributed so largely to the limestone formation—are Corals, Encrinites or Sea Lilies, Productus, Rhynconella, Terebratula, Euomphalus, Bellerophon, Aviculopecten, and Spirifera.

They all vary in size and structure. The Faraminifera is very minute indeed, but they swarm over large areas of the sea in warm parts.

135. Classification of limestone:—The limestone formation, like many other material substances in nature, although composed of nearly one and the same species, appear at the earth surface in a variety of forms, and may be divided into a series of which—1st, limestone appears as chalk in the Cretæous; 2nd, as forest marble in the Oolite; 3rd, as common gray limestone in the Lias; 4th, as magnesian limestone in the Permenian; and 5th, as mountain limestone in the Carboniferous.

136. In each of the above enumerated forms in which the limestone appears, the carbon plays a most important part, and in no form does it exist in which that element is entirely absent; but owing to the disturbing elements which are constantly going on in the seas and on the land near the coast, it appears in some respects very impure. The following chemical outlines of their formation will give the young student a more clear idea on the subject:—1st, When Calium appears as a carbonate (Ca Co3), it constitutes limestone, marble, and chalk, and also the crystallized minerals—Arragonite and Iceland spar; 2nd, when it appears as a sulphate (Ca S04), it occurs in Gypsum, Alabaster, and Selenite; and 3rd, when it appears as a phosphate Ca 3, (Po 4) 2, it forms the principal constituent of the bones of animals, while the shells of those several groups of the Mollusia, which contribute so largely to the limestone formation as has already been said, consists almost entirely of

calice carbonate; and when each of the different forms are examined, whether they belong to the Crataceous, Oolitic, Liasie, Pernian, or the Carboniferous, they are found to contain nearly one and the same species, varying only in a limited degree.

137. Commercial properties of Limestone:—Limestone from a commercial point of view, must be regarded from the four cardinal points in which it stands related to our industries: 1st, as a building mortar for general purposes; 2nd, as building-stone, of which the dalomite is a fair specimen. It is one of the varieties of the magnesian limestone, and is more or less crystalline. It was selected by a Royal Commission as the material for the erection of the present Houses of Parliament; 3rd, as an ingredient of compost, for loosening and lightening the soil; and 4th, as an ingredient with fluxing ores in the manufacture of pig-iron.

138. Chalk.—Chalk is a beautiful fine white lime, which is well adapted for plastering the inner walls of buildings, owing to its tough nature and exceedingly fine texture.

It is largely used in chemical work for the manufacture of sodic-carbonate (Na2 Co3 10H20), which is a very important substance in bleaching, glass-making, soap-making, etc.

139. Charcoal.—There are four separate and distinct kinds of charcoal, all of which play an important part in the arts, and may be characterized as wood and animal charcoal, coke, and lamp-black.

140. Wood and animal charcoal is obtained by heating the wood and animal substances in retorts until they evolve the whole of the water and volatile matter contained in them, which consists of hydrogen, oxygen, and nitrogen, leaving the carbon in the form of charcoal behind.

Coke or charred coal is obtained by heating the coal in an oven or retort till it parts with all the volatile matter it contains; and lampblack or soot is obtained by burning any inflammal body containing carbon and

hydrogen, in such a way as to allow the flame to come in contact with some substance such as rock, on which the unconsumed carbon is deposited, and which is easily collected when cold.

141. Wood charcoal is employed in the arts as fuel, and forms 15 per cent. by weight of gunpowder; animal charcoal, bone or ivory black, is a valuable re-agent as a bleaching powder, and is used by sugar refiners to deprive brown sugar of its colouring matter, by filtering it through a stratum of the powder; it removes the colour from liquids that owe their tint to the presence of animal and vegetable matter, and may be regarded as a valuable disinfectant. Lampblack soot, or condensed smoke, is employed in the arts in the preparation of pigments or paints, and coke is extensively used for steam and manufacturing purposes.

142. Having briefly reviewed the elements which form the bases of the inflammable gases met with in mines, we must refer the student for further information as to the distribution of carbon in the formation of rocks and minerals, and the cardinal principles of living structure, to works on Chemistry, Geology, Animal and Vegetable Physiology.

VENTILATION.

The circulation of a sufficient current of pure air to meet all necessary requirements.

143. The ventilation of a mine is the most important subject of mining engineering, and little doubt remains in the minds of thorough practical experienced agents, that a lack of knowledge on this principle is the fruitful cause of colliery explosions in this and other countries.

In order to understand the principle so as to be able to ventilate a mine efficiently, under every conceivable difficulty in which it is possible for a mine to be situated, under-ground agents, from the deputy-overman to the

manager, should possess a thorough practical knowledge of pneumatics and the laws of motion.

144. Pneumatics.—Pneumatics from the Greek word "Pneuma," "breath," or "air," and proper, the science of æriform fluids, have already been considered at some length in the previous paragraphs from 2 to 127.

145. Force.—Force means a power which gives rise to the law of motion; motion means a change of places, and its opposite means rest; hence the two fundamental laws—"Inertia" and "Motion."

146. Inertia.—Inertia and motion simply means the negative and positive action of force; the former implies that when a body is at rest, it requires force to put it in motion, and when once in motion it also requires a force equal to the force it contains within itself to arrest its motion by restoring it to a state of rest; so that the student will see from this principle, which results from opposite actions, that the law of "Inertia" exerts no influence whatever, either in accelerating or retarding the motion of a body, but is confined within the limits of inactivity.

147. It is a property of matter to be inert, a body at rest as aforesaid, requires force to put it in motion, and when in motion, it requires force to arrest it; equal forces in opposite directions, when brought in contact, neutralize each other, and when a body is set in motion, setting opposite forces aside, there can be no reasonable grounds for supposing that it would ever stop, but that it would continue to move onward in the same direct line in which it commenced to move for ever, by the property of its own inherent law, Inertia; for every body must be under the influence, so to speak, of one or both of those laws—moving or resting.

148. The ventilation of a mine is conducted by means of a pair of pits, levels or drifts; the one is known as the downcast or intake, and the other as the upcast or outlet, and the air which passes down or into and around the workings through the former and returns back to

the surface by the latter, is called the ventilating current of the mine.

And the ventilating current or atmosphere is in every respect, under the same influence with regard to its motion and rest as all other bodies are.

If therefore, it takes a force to put the air in motion, considering the resistance it meets with from friction, etc., it must be evident that the same amount of force will be required to keep it in motion.

149. Motion.—The motion of the atmosphere (apart from its common motion as an appendage to the earth, for every body may be regarded as being in possession of a common motion in connection with the body on which it rests), is due to its own elasticity, and its elastic spring is in proportion—1st, to the weight with which it is compressed; or 2nd, to the degree of heat or cold to which it is subjected, whereby its volume is either expanded or contracted; and 3rd, to the law which regulates the speed of a falling body, in falling from one point to another point in space in a given time.

Under such conditions, the ventilating current of the mine will be in proportion—1st, to the force applied to it; 2nd, to the area of the air passage; and 3rd, to the degree of resistance it encounters in its course.

150. Common Motion is the motion of a body which is resting on another body that is in motion, as a passenger in a railway carriage has a common motion equal to the speed at which the train is moving, and

Incline motion is governed by the law of Specific Gravity and Inertia. A ball resting on a level plane presses on its centre with the whole force of its gross weight, in which case it is under the influence of both laws—"Inertia" (resting), "Gravity" (pressing).

If the plane on which the ball rests be raised up at one end, the ball will be put in motion by the force of gravity and by the law of "Inertia"; if gravity should cease to exert an influence on it beyond this preliminary

act, the ball would still continue to move (setting friction aside) in a straight line at the same speed, but minus its accelerating force.

151. The motion of a falling body, is according to the squares of the times—A light and heavy body will both fall in vacuum at the same speed, and the velocity of a falling body with an accelerated motion is 16 feet 1 inch the first second of time; at the end of the first second it will be moving at the rate of 32 feet per second, and but for the law of gravity, it would continue on at that speed for ever; but its influence on the body being unabated, it imparts an additional speed of 16 feet, causing the body to fall 48 feet in the second second, with an accelerated motion equal to 64 feet with which to commence the third second; so that the distance a body will fall in a given time, can be easily ascertained from the following examples, thus:—At what speed is a falling body moving through space at the end of two seconds, three seconds, four seconds, and five seconds respectively? Here $2 \times 2 = 4 \times 16 = 64$ at the end of the second second; $3 \times 3 = 9 \times 16 = 144$ feet at the end of the third second; $4 \times 4 = 16 \times 16 = 256$ feet at the end of the fourth second; and $5 \times 5 \times 16 = 400$ feet at the end of the fifth second.

152. Natural and artificial ventilation.—The internal heat of the mine, accelerated by the workmen and their lights, exert a certain influence on the ventilation; the internal heat of some mines is sufficient of itself alone to keep up the ventilating current required, but as a rule natural ventilation is not sufficient to secure life and property in all mines, hence the necessity of applying artificial means to assist nature in this respect; but it must be borne in mind, that whatever be the mechanical force applied to increase the quantity of air passing in the mine, apart from enlarging the area of the airways or shortening their distance, will be at the cost of an equal amount of resistance; for if it takes a force equal to 4 h.p. to keep up a current of 10,000 cubic feet of air per minute to double that quantity, or

to put 20,000 cubic feet per minute in motion in the same air passages, will take a force equal to 16 H.P., as $4 \times 4 = 16$.

153. The natural current of the air in moving through the mine is not impeded by either length or area of air passage; it is, however, impeded to a small extent from the roughness of the airway, accelerated slightly by its greater density than the surface air, otherwise, it moves as freely in the mine as at the surface, so that the length and area of the air passage under such conditions exert no influence on the air in motion, for the air will travel just as steady in a long passage as it will travel in a short one, providing that both the air passages be situated on the same even or level plane. If, however, one passage be to the dip and the other to the rise, and they be one and the same distance from the outlet, the difference of the quantity of air passing in each channel will be in proportion to the difference of the level from the bottom of the downcast from where both the currents proceed, assuming that the internal heat be the same in both sections.

154. The artificial means made use of to assist nature in the ventilation of mines, consists principally of the Fan and Furnace, and the way in which they are applied to effect this object is as follows:—1st, the return current is passed over a large furnace at the bottom of the upcast, thereby raising its temperature above, and by this means reducing its density below that of the intake air, and the difference between the weight of air in the downcast and upcast shafts is the motive power, which gives effect to the ventilating current; and 2nd, a Fan is fixed at the top of the upcast of a given diameter, and is attached to either a water wheel or a steam engine, which draws by suction a given amount of air from the mine at every revolution it makes, the suction acting on the same principle as a vacuum of given dimensions would act under such conditions.

155. Furnace Ventilation.—The power obtained by

furnace ventilation, as just set forth in the last paragraph, is measured by the difference of the weight of air in the downcast and upcast shafts, as may be seen in the following examples:—If the temperature of the downcast be 50 degs., and the upcast 130 degs. of Fahrenheit's heat scale, what will be the difference of the weight of a cubic foot of air in the lower against a cubic foot of air in the higher temperature? Here 0.0765546 lbs. (the weight of a cubic foot of dry air), is multiplied by 60 plus the expansion due to the air for every degree of heat to which it is raised, viz.:—1-459th part of its own volume, and that product divided by the temperature of the shaft plus, the constant 459 gives the weight of a cubic foot of air in each shaft according to its temperature, and the lighter being subtracted from the heavier gives the mean difference of weight between them. Example—$.0765546 \times \frac{60+459}{50+459} = .0765546 \times \frac{519}{509} = .0780586$ lbs., the weight of a cubic foot of air in the downcast, and $.0765546 \times \frac{50+459}{130+459} = .0765546 \times \frac{509}{589} = .0674564$ lbs., the weight of a cubic foot of air in the upcast, then $.0780586 - .0674564 = .0106022$ lbs., the difference of weight per cubic foot between the temperatures of 50 degs. and 130 degs. as required.

156. To find the entire weight of air in each shaft, and the difference of weight between them, multiply the cubical area of each shaft respectively by the weight of a cubic foot of air due to the temperature of the said shaft, and that product plus or minus the weight of air in the other shaft will be the difference of weight between them, and that difference will be equal to the motive power required to keep up the ventilation of the mine.

If the cubical area of a pair of shafts, upcast and downcast, be 23,000 feet each, the temperature being 50 degs. and 130 degs., what will be the weight of air in each shaft and the difference of weight between them under such

conditions? Example—.0780586 × 23,000 = 1795.3478 lbs., the weight of air in the downcast of 50 degs., and .0674564 × 23,000 = 1551.4972 lbs., the weight of air in the upcast of 130 degs., then 1795.3478 − 1551.4972 = 243.85 lbs., the difference of weight in the two shafts.

157. Motive Column.—To find the motive column from the difference of the weight of air in the two shafts —multiply the difference by the depths of the shaft in feet, and divide that product by the entire weight of air in the downcast, and the quotient will be the length of the motive column.

If the quantity of air in the downcast weigh 1795.3478 lbs., the depth of the pit measures 300 ft., and the difference of the weight of air in the two shafts be 243.85 lbs., what will be the length of the motive column?

Example.—As 1795.3478 : 300 :: 243.85 : 40.74 feet, length of the column required.

158. To find the length of the motive column from the depths of the shaft and the temperature of the upcast and downcast respectively, multiply the depth of the shaft in feet by the temperature of the upcast, minus the temperature of the downcast, and divide that product by the temperature of the upcast, plus the constant 459, and the quotient will be the length of the motive column in feet.

The length of the motive column of a ventilating shaft is required, the downcast being 50 degs., and the upcast 130 degs., and the depth of the pit 300 feet.

Example.—$300 \times \frac{130 - 50}{130 + 459} = 300 \times \frac{80}{589} = 40.74$ ft., the same as in the preceding example.

159. It will be seen from the two preceding examples that the column of air in the downcast would balance a column of air in the upcast, both pits being of the same depths and superficial area—40.74 feet higher than the length of its own column, so that the difference of density between the upcast and downcast current of air must be regarded as a vacuum equal in length to the

motive column, and of the same superficial area as the upcast shaft.

160. A falling body rushes into a vacuum at a velocity equal to eight times the square root of the length of the vacuum (see 151), and the difference of density between the intake and return air, which represents a vacuum 40.74 ft. (see 157-8), is the motive power that gives effect to the ventilation of the mine, so that $\sqrt[2]{}$ of the vacuum (apart from friction) represents the speed at which the air is moving through the mine per second.

Now—$\sqrt[2]{}40.74=6.38\times 8=51.04$ feet, the apparent velocity of the air current per second, 3062.4 feet per minute, or 34.8 miles per hour. Now every practical mine agent knows that air travels at no such speed in the mine, and the force required to generate this theoretical velocity is 22.62 H.P.—for 243.85 lb. × 3062 ft. ÷ 33.000 lb. = 22.62 H.P.

But in consequence of the resistance the air meets with in its passage through the galleries of the mine, its apparent velocity is reduced to about 1-6th of that amount, or to about 512.6 feet per minute, and the force to generate this motion (apart from friction) is 3.81 H.P., for $243.85\times 512.6\div 33.000=3.81$ as before stated.

The difference between the apparent and real velocity of the air current in the mine, brings us next to the consideration of resistance.

The amount of frictional resistance is estimated by the amount of force required to overcome it, and the force required to overcome the friction of the air increases and decreases in the same proportion as the extent of the rubbing surface, to which the air is exposed, increases or decreases. The friction of the air may be considered in the following order, viz.:—1st. From the length of the air passage, or the extent of the rubbing surface to which it is subjected; 2nd. From the Perimeter of the airway, that is the sum of all its sides; 3rd. From the velocity or speed at which the air is moving, and

4th. From the density of the column, or inversely as the area of the air passage.

FRICTIONAL RESISTANCE.

161. Friction means a counteracting force, excited by a body in motion, and is measured by the amount of force that is employed to overcome its resistance. Therefore, the resistance to the air in motion depends on the four fundamental principles laid down in paragraph 160.

Where the intake and return represent the same area, making due allowance for the difference of the perimeter between the square and circular passage, the friction will be equally distributed through the entire length of the air column, providing that the airways be of the same sectional area in the different districts of the mine, and to enlarge any portion of one of them, will not by any means lessen the amount of friction in any part of the unenlarged passage.

The difference of frictional resistance between the square and circular passage, both being of the same area—1, is as 7 is to 8 nearly, that is to say—that the square passage would offer as much resistance to the air in motion in a passage 700 yards long as the circular passage would offer to the air in a passage 800 yards long, for the perimeter of a circle whose area is 1=3.545, and the perimeter of a square whose area is likewise—1=4, and $3.545 \times 2 = 7.09$ and $4 \times 2 = 8$, so that the former is to the latter as 7 is to 8 nearly; hence therefore, the student must understand that the nearer the airways approach to the form of a circle, the less will be the frictional resistance offered to the air in motion.

162. Resistance.—The resistance increases or decreases in proportion to the extent of the rubbing surface or the length of the airway.

Take two airways of equal length and area, through which 30,000 cubic feet of air is passing in two divisions of 15,000 cubic feet each per minute, alter one of them

so as to reduce its length by 1-4th, thus making them to represent the entire length of the airways in the proportion of 3 to 4, equal to $\frac{3}{7}$ and $\frac{4}{7}$ respectively, or the entire length to $\frac{7}{8}$ of the original length; by this means the equilibrium of pressure or resistance between the two airways would be destroyed by the reduction, as aforesaid, of one-fourth the length of one of them, which would cut off 1-8th the rubbing surface, in consequence of which the air would rush into the short route until the resistance became equal in both the airways. The result of this change would cause $\frac{4}{7}$ of the air, or 17,143 cubic feet per minute to pass through the shortway, while only $\frac{3}{7}$ or 12,857 cubic feet per minute would pass through the long airway, as $30,000 \times \frac{4}{7} = 17,143$ cubic ft., the quantity the short route would take, and $30,000 \times \frac{3}{7} = 12,857$ cubic ft., the quantity which would pass through the long route.

From this example it will be seen, that to shorten the airways is one of the best means of increasing the quantity of air in mines.

163. The resistance increases in proportion to the extent of the perimeter of the airway, that is to say, the breadth of the top and bottom and height of the sides.

If for example we take two airways, each 64 ft. square $8 \times 8 = 64$, and alter one of them so that it will retain the same area in an altered form, say $16 \times 4 = 64$ square ft., the perimeter of the quadrilateral 8×8 would be 32 as $8 \times 4 = 32$, and the perimeter of the rectangle or parallelogram would be 40, as $16 + 4 \times 2 = 40$, or $(16 + 16) + (4 + 4) = 40$; now the quantity of air taking the 30,000 cubic ft. as before, that would pass through the quadrilateral passage with a perimeter of 32, would be 16,666 cubic ft., as $30,000 \times \frac{40}{32+40} = 30,000 \times \frac{40}{72} = 16,666$ cubic ft. per minute, while the parallelogram with a perimeter of 40, would only pass 13,333 cubic ft., as $30,000 \times \frac{32}{40+32} = 30,000 \times \frac{32}{72} = 13,333$ cubic ft. per minute, making a mean difference in favour of the lesser perimeter of 3,333 cubic feet per minute. (See latter part of 161.)

164. The resistance increases according to the squares of the times, that is to say, if it take a force equal to 4 H.P. to move a column of air 300 feet per minute, to move the same column of air 600 feet per minute would require a force of 16 H.P., as $4 \times 4 = 16$ (see 152) in this example, double the quantity of air would be put in motion, but at four times the cost, so that it is not economising the expenditure to increase the quantity of air in mines by increased velocity; the quantity of air passing through the mine should be sufficient for all practical purposes at a velocity of five miles per hour or 500 feet per minute, and to increase the quantity of air in circulation, it should be done by enlarging the area and shortening the length of the air channels.

165. The resistance increases inversely as the area of the air passage, that is to say—If it take a force equal to 4 H.P. to produce 30,000 cubic feet of air per minute in an air passage of 64 square feet, it will take a force of 16 H.P. to produce the same quantity in the same time in an air passage 32 square ft., as 32^2 is to 64^2; as 4^2 is to 16.

166. The resistance is accelerated in proportion to the roughness or unevenness of the sides of the air passage—that is to say, where the airway is driven in a straight line from the intake to the boundary, and from the boundary to the outlet, accompanied by an even and regular surface of the top, bottom, and sides of the air channel, the frictional resistance is less than where the airway is driven in a zig-zag line, accompanied by nooks or corners projecting out hither and thither along the whole passage, so that the straighter and smoother the passage the less resistance will be offered to the air in motion. Water in motion forms its own lining, so that it moves as rapid through a rough channel as it moves through a smooth one; the slight resistance due to the motion of water is from the law of cohesion, in consequence of its globular particles rolling one over another, tearing as it were themselves asunder, the current

always moving more rapid in the centre of the channel. It is the same to a certain extent with the air; it always moves more rapid in the centre than at the top, bottom, or sides of the air passage. This, however, is due to the law of friction, as the particles of the air are not governed or influenced by the law of cohesion, but by the law of repulsion.

167. Resistance.—In the five preceding paragraphs we have pointed out the principle causes of frictional resistance to the air in motion; there is one more principle bearing on this subject, which we consider merits a place in this work, viz. :—That the resistance is in proportion to the difference of areas; for instance, suppose two airways, one six ft. square and the other 12 ft. square, each airway being 5000 feet long, $6 \times 4 = 24 \times 5000 = 120{,}000$ feet of rubbing surface, and $12 \times 4 = 48 \times 5000 = 240{,}000$ feet of rubbing surface in the large airway. In this example there is double the amount of rubbing surface in the large that there is in the small way, but to compensate for this difference the area of the large way is four times larger than the area of the small way, for $6 \times 6 = 36$ and $12 \times 12 = 144 \div 36 = 4$, so that four times the quantity of air would pass through the large airway that would pass through the small way for double the amount of friction per square foot. In this example it is plain that the larger the area of the airways the less will be the frictional resistance to the air in motion.

DISTRIBUTION OF THE AIR CURRENT.

168. Distribution of the Air.—The length of the air passage depends on the area of the workings, and the number of sections into which it is divided. A mine that gives off a large quantity of inflammable gas, carbonic-dioxide, or black damp, or one where a large quantity of blasting powder is used, as in the Cleveland mines, the entire area of the workings should be

parcelled off into small sections of about 10 working places each, each section being supplied with a separate current of pure air.

169. The quantity of air required for each section will depend—1st. On the number of workmen who are employed in that locality, including their lights and horses; and 2nd. The area of the workings and the quantity of gas that is issuing from the fissures of the strata. Where the maximum pressure of the gas is below or does not exceed the minimum pressure of the air, the quantity of air passing through such a section should not be less than 400 cubic feet for each workman per minute; if, however, the minimum pressure of the gas per square foot be equal to the maximum pressure of the air, and this state of things represent each section of the mine, it is then a question as to whether such a mine can or ought to be worked on the present principle on which the ventilation of mines is conducted; but, should the minimum pressure of the gas exceed the maximum pressure of the air, nothing can be more certain than to work such a mine on the present system would destroy the lives of the workmen and the property of the owners. Under such circumstances, the question may be raised—How are such mines to be worked? and what, if any, compensation should be made to the owners for the loss they would sustain by the stoppage of them?

In answer to the 1st question, the writer would suggest, that where the commercial value of the mineral was sufficient to meet the increased expenditure that would arise from the alteration required, and the maximum pressure of the gas was, say 15 lb. per square inch, 1-20th the quantity of air necessary for the mine on the present mode of ventilation, should be put into circulation under a pressure of 30 lbs. per square inch, and governed by air locks instead of doors; that is to say, if the state of the mine required 400 cubic feet of air per minute for each workman under a pressure of

one atmosphere of 15 lbs. per square inch, the entire volume of air being put under a pressure of two atmospheres, would only require a current of air in circulation of 20 cubic feet per minute for each workman, as the extra pressure of 15 lbs. per square inch would have the same effect on the pent up gases in the mine as the weight on the safety valve have on the steam in an engine boiler, so that under such an arrangement an *explosion* of *gas would be impossible*, and the *safety lamp would not be required*. Under such circumstances, the escape of gas from the fissures of the strata would be governed exclusively by the law of diffusion (see 62 to 72), which could do no harm to the ventilation.

And his answer to the second question would be—That where the Government found it necessary to stop a mine, in order to prevent the sacrifice of human life, they ought to reimburse the owner the amount of money expended in the undertaking.

The only reasonable objection that can be raised against the introduction of this principle to the ventilation of fiery mines, is the extra cost the machinery would incur to keep up the ventilating current under such a pressure, and the impediment it offers to the transit in the working roads by the use of air-locks, as each set or load of tubs would have to stop between them until the pressure of the air was either raised or lowered to the same pressure of the air in the side of work to which they were going. What amount of force would be required to keep up a ventilating current of 5000 cubic feet of air per minute under a pressure of 30 lbs. per square inch? Here $5000 \times 144 \times 30 \div 33{,}000 = 654.54$ H.P. Under such conditions the air current should not exceed 90 feet per minute. Having briefly laid down the principle upon which a fiery mine can be worked with naked lights without incurring the slightest risk of an explosion of fire-damp, the writer leaves the matter in the hands of the mine-owners and those who are concerned, believing that they have sufficient experience on

the subject, to enable them to apply it where the state of the mines requires and the commercial value of the mineral will admit of its adoption.

170. The entire volume of air should be divided into two or three sections at the bottom of the downcast pit, each section being of sufficient area to admit and conduct at the minimum rate of friction, one-half or one-third, as the case may be, the quantity of air passing down the shaft, and each main airway should be divided as near to the downcast as possible, into as many sub-sections as the advanced state of the workings require, in order to limit the length of the air channels to the shortest possible distance.

Objections have been made against the principle of splitting the air into more than two or three sections, urging as a plea of justification, that too many splits destroys the effective working force of the air current in the mines; as this is simply a whim that will not bear the slightest investigation, therefore further comment is unnecessary.

171. Each division of the air should be governed by frame graduated regulators, and the slide of each should be secured by a lock to prevent any one tampering with them; the area of the air passage at the regulators should be carefully adjusted, so as to meet the requirements set forth in the forepart of the last paragraph (169).

Regulators as well as doors are an obstruction to the air current, but as it is necessary for the proper ventilation of mines to have one of them, the regulator is preferred—1st. Because it is more simple in its construction, less expensive, and is less liable to derangement; and 2nd, because it only offers one outlet for the air current, whereas every door offers two outlets, which is a double injury to the ventilation.

172. Every section of the mine whether at work or not should be ventilated, including the goaf, and the return current should be made to sweep the edge of the goaf in its passage from the face workings to the

upcast or outlet, but on no account should a current of air pass through any section of the goaf to the workings.

The manager who would indulge in such a reckless undertaking, and thereby place the lives of the workmen and the property of the owner under such imminent risk, ought to be at once discharged from his office for incompetency, as it would be quite as safe to pass a shovel full of red hot cinders across a magazine filled with loose gunpowder, as it would be to pass a current of air across the goaf of a fiery mine to the working places. In the former case it would require the cinder to fall from the shovel on to the powder to cause ignition, but in the latter case the gas of the goaf would mix or diffuse itself through the air current in its passage, and would thus be borne on to the workman's lights, where all the horrible effects of an explosion of fire-damp could be witnessed.

It was in consequence of the intake air passing over the goaf to the working places in a certain section of the mine, that caused the explosion of fire-damp at the the Wood Pit of Haydock, near St. Helens, Lancashire, on the 7th of June, 1878, and as two eminent Mine Engineers—Messrs Greenwell and Topping, attended the Coroner's inquest, the former on behalf of the Government, and the latter on behalf of the mine-owners —would it not be well to know on what principle this theory is reconciled with the "Science of the Mine."

Should the return air current be charged with gas to such an extent as to risk an explosion at the furnace, it should be either mixed with pure air from the intake, to reduce it below the explosive point, or the gas should be conducted into the upcast at a distance of 50 ft. above the furnace by means of a drum-drift. (See d.d., fig. 16).

173. In order to prevent an accumulation of gas in the mines, which is the principle cause of colliery ex-

plosions, an escape drift should be driven from the upcast into the summit of the goaf, providing the overlying measures are bound by a strong post girdle, which can resist the draw of the goaf to the surface. By this means the gas would escape to the upcast as fast as it was given off, but where the upper measures consists of loose shaly matter, and each fall in the broken section or goaf reach the surface, an escape drift would be of no benefit whatever in this respect, but the gas in this case would find its way into the return airway under certain atmospheric changes, and would in connection with the return current, ascend the upcast. The diagram (Fig. 16) shows the way in which the air should be divided off into separate sections:—At the bottom of the downcast D, three distinct currents of air, S.S.S., after passing around the workings, are re-united at B.B. in the furnace drift or main return before it pass over the furnace F. to the upcast U, the gas of course in the return current passing through the drum-drift d.d., and the gas that is given off in the goaf passes through the escape drift e.d., and thus unites with the return air at U., and ascends to the surface; the area of S.S.S. and B.B. should each be equal to the area of D or U (see 161).

DAILY INSPECTION.

174. Daily Inspection of Mines:—The examination of the working places and horse roads. This principle has been in operation for many years in some form, but it is doubtful whether ever it has been conducted on such a principle as the dangerous nature of fiery mines require.

It is not the intention of the writer to discuss all the minute details of this important branch of mining engineering, but he may say that up to the present the inspection of mines has been confined—1st, to the state of the ventilation, that is to say, whether there be a sufficient quantity of air passing through the mine to support the

flame of a lamp or candle; 2nd as to the general state and condition of the workings; and 3rd, as to the state and condition of the return airways and the working roads, to ascertain whether anything has occurred in them that is likely to obstruct the ingress and egress of the air, or to impede the transit of materials, also to ascertain whether there be a sufficient quantity of timber and skirting brattice to meet the ordinary requirements of safety in each section of the mine.

However much we admire this principle, as far as it goes we are satisfied, that to make the inspection efficient, the pressure of the gas per square inch should be taken and properly recorded in the Report Book, in the next column to the atmospheric pressure, so that the difference of pressure between the gas and the air being known, the inspector would be able to calculate more accurately the real state of the ventilation, because the escape of the gas from the fissures of the strata into the air is in proportion to the difference of the pressure of the two fluids apart from the common law of diffusion, a principle that always exist regardless of atmospheric pressure (see 68).

The common law in use to ascertain the quantity of gas that may be expected to be given off when the mercury falls in the barometer, which indicates a change of atmospheric pressure is as follows:—From the higher number of inches and tenths of an inch of the barometer before the fall of the mercury took place, subtract the lesser number of inches and tenths to which the mercury has fallen, and then say, as the higher number is to the difference of the two numbers, so is the area of the mine to the number of cubic feet of gas that should be given off in the mine under such conditions; but as it is not convenient to ascertain at once, or in so brief a time the entire area of the underground workings, fix the area at 1000 square ft., and the quantity of gas given off per 1000 square ft. will be uniform per 1000 square ft. area of the whole mine, providing that the pressure of the gas be

uniform throughout the entire mine. Example—What quantity of gas may be expected to be given off per 1000 square feet area per minute when the mercury falls in the barometer from 30.50 inches to 29.80 inches? Example—

From the higher number, ...30.50
Subtract the lesser number....29.80

and the quotient will represent the mean difference,..... 00.70

then say, as 30.50:0.70::1000:21.35 cubic feet the extra quantity of gas that should be given off per 1000 of square feet area under these conditons.

175. This law or rule holds equally good when applied to the pressure of the gas as when it is applied to the pressure of the air, as just illustrated in the above paragraph, but does it convey to the mind of the Inspector the entire quantity of gas that has been given off in the mine or in any section of the mine when the atmospheric pressure is unaltered?—It does not. Then of what benefit is this first principle in our inspection operation either to the employer or the employed, seeing that it does not define either the pressure or quantity of gas liberated in the mine under such conditions?

Certainly no intelligent person will be so thoughtless as to approve of a report where the inspector can only say we have more or less gas given off to-day in the mine than we had yesterday, and it must be born in mind, that on the present mode of inspection, this is all that he can say. It may be said by some well-disposed persons, we judge the quantity of gas given off in the mine from its appearance in the safety lamp, but such a statement would be inadmissable, because it would not define the quantity. As the quantity of gas given off in the mine can only be known by ascertaining its pressure in the measure along with the pressure of the air in the mine, it proves that the present principle of daily in-

spection in our fiery mines is defective and misleading; therefore, to make the inspection what it ought to be, by defining the amount of gas that is being liberated from the mineral measures, and mixing up with the air current, the pressure of the gas must be tested in each section of the mine, which can be easily done by means of a gauge which is provided with an exhaust tube.

176. The following table shows the pressure of air per square inch and square foot respectively, from the height of the mercury in the barometer being multiplied by .4908 lbs. the weight of a cubic inch of mercury, which gives the atmospheric pressure per square inch, and that product being multiplied by 144 gives its pressure per square foot:—

Height of Barometer in inches.	Pressure of air per square inch in lbs.	Pressure of air per square foot in lbs.
27	13.2516	1908.230
27 1-10th	13.3006	1915.297
27 2-10th	13.3416	1921.190
27 3-10th	13.3988	1929.432
27 4-10th	13.4479	1936.500
27½	13.4970	1944.568
27 6-10th	13.5460	1950.635
27 7-10th	13.5951	1957.703
27 8-10th	13.6442	1964.770
27 9-10th	13.6933	1971.838
28	13.7424	1978.905
28 1-10th	13.7914	1985.973
28 2-10th	13.8405	1993.040
28 3-10th	13.8896	2000.108
28 4-10th	13.9387	2007.175
28½	13.9878	2014.243
28 6-10th	14.0368	2021.310
28 7-10th	14.0859	2028.378
28 8-10th	14.1350	2035.445
28 9-10th	14.1841	2042.513
29	14.2332	2049.580

Height of Barometer in inches.	Pressure of air per square inch in lbs.	Pressure of air per square foot in lbs.
29 1-10th	14.2822	2056.648
29 2-10th	14.3313	2063.715
29 3-10th	14.3804	2070.783
29 4-10th	14.4295	2077.850
29 5-10th	14.4776	2084.774
29 6-10th	14.5276	2091.987
29 7-10th	14.5767	2099.053
29 4-5th	14.6258	2106.120
29 9-10th	14.6749	2113.188
30	14.7240	2120.256
30 1-10th	14.7730	2127.323
30 2-10th	14.8221	2134.391
30 3-10th	14.8712	2141.458
30 4-10th	14.9203	2148.526
30 5-10th	14.9794	2157.033
30 6-10th	15.0184	2162.650
30 7-10th	15.0675	2169.728
30 8-10th	15.1166	2176.796
30 9-10th	15.1657	2183.863
31	15.2148	2190.931
31 1-10th	15.2638	2197.998
31 2-10th	15.3129	2205.066
31 3-10th	15.3620	2212.133
31 4-10th	15.4111	2219.201
31 5-10th	15.4602	2226.268
31 6-10th	15.5092	2233.336
31 7-10th	15.5583	2240.403
31 8-10th	15.6074	2247.471
31 9-10th	15.6563	2254.507

MEASUREMENT OF THE VENTILATION.

177. To measure the quantity of air passing into the mine or any section of the mine, the inspector should select a certain place in each intake and return section as well as in the main intake and main return airways.

Where he could obtain the exact area of the passage or the place where he is to measure the current of air, that is to say, the breadth of the bottom and top and height of the sides must either be added together, which equal the area of the place selected, or one of the sides must be multiplied by the mean breadth of the passage which will give the area required. What is the area of the air channel where the breadth of the top is 5 ft. 9 in., the middle 7 ft. 9in., the bottom 7 ft. 6 in., and the height of the sides 9 ft. ?

Example:—$5\frac{3}{4}+7\frac{3}{4}+7\frac{1}{2}=21\div 3=7$ feet, the mean breadth, and $7\times 9=63$ square feet, the area required.

178. Anemometer.—The area of each section being known, an instrument known by the name of the anemometer, which is used in all the most important mines in the country, is set on the ground or bottom of the passage, and the number of revolutions the vanes make per minute is entered in a book or on a slip of paper; the instrument is then raised to the middle or to half the depths of the airway, and the number of revolutions made by the vanes in that position are added to the other, which being divided by two, gives the mean velocity, or what is the same, the mean number of revolutions per minute, which should be entered in the Inspector's Report Book.

Every revolution of the vanes records one lineal foot the air has travelled, so that the number of revolutions made per minute being multiplied by the area of the passage, gives the number of cubic feet of air passing through that section of the mine per minute. Example: —What is the quantity of air passing through a section of the mine where the number of revolutions of the vanes of the anemometer are 600 per minute, and the area of the air-gate is 81 square feet? Here $81\times 600=$ 48,600 cubic feet per minute. Again, what is the quantity of air passing through the main airway, the area of which is 144 square feet and the revolutions of the vanes of the anemometer are 950 per minute?

Example:—950 × 144=136,800 cubic feet per minute.

If the stoppings that separate the intake air from the return be kept perfectly air tight, and the skirting brattice close up to the face workings, under such conditions the entire quantity of air passing into the mine will sweep every section so completely that an accumulation of gas will be impossible; but unfortunately, it is common enough to find in some mines, from one-fourth to one-third of the entire quantity of air in the mine passing out to the surface without going near the face workings. This is however, the result of bad management, and it is found generally in those mines which are governed more by theory than practice.

179. Drag of the Mine.—The quantity of air passing through each section of the mine being clearly defined by the anemometer, the Inspector has next to ascertain the drag of the mine—frictional resistance. This is done by means of a water gauge, which is a glass tube bent into the form of the letter U and mounted at the end of one of its limbs with a brass tube in the form of a right angle, one of its ends fitting into the hole of a door, or a stopping as the case may be, which divides the intake air from the return air, so that the limb that is mounted is exposed to the action of the return current, while the other limb is open to the pressure of the intake current.

The gauge is provided with a scale of inches and decimal parts of an inch for reading the difference of the height of water in the two limbs, and before making the experiment, the gauge should be filled about half full of water. In consequence of the force expended in overcoming the resistance of the return air in its passage through the mine, its density is reduced below the density of the intake air, which has not been subjected to the same extent of rubbing surface, in consequence of which the water is pressed down the limb of the tube that is exposed to the action of the intake air, while it rises up the other limb that is exposed to the action of the return air to the same degree of height, so that one-half the

difference of the height of water in the two limbs equal the "Drag" of the mine, or shows the amount of force that has been expended in overcoming the frictional resistance to the return air per square foot.

A cubic foot of water weighs 62.5 lbs. or 1000 oz., and a square foot of water one inch deep weighs 5.20 lbs., so that 5.20 becomes the multiplier to all problems bearing on frictional resistance of the air when tested by the water gauge. Example—What is the amount of friction upon every square foot of air that is passing through a mine where half the difference of the height of water in the two limbs of the water gauge measures $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $2\frac{1}{2}$, $2\frac{3}{4}$, and 3 inches respectively?

Here—	$\frac{1}{4}$	$= .25 \times 5.2 =$	1.30	lbs. per	square foot.
,,	$\frac{1}{2}$	$= .50 \times 5.2 =$	2.60	,, ,,	,,
,,	$\frac{3}{4}$	$= .75 \times 5.2 =$	3.90	,, ,,	,,
,,	1	$= 1.00 \times 5.2 =$	5.20	,, ,,	,,
,,	$2\frac{1}{2}$	$= 2.50 \times 5.2 =$	13.00	,, ,,	,,
,,	3	$= 3.00 \times 5.2 =$	15.60	,, ,,	,,

In the above example the student will see that the minimum rate of friction is fixed at $\frac{1}{4}$ inch of drag, or water-gauge=1.30 lbs. per square foot of air, and the maximum at 3 inches=15.60 lbs. per square foot of air. The first four examples would represent a good working state of the ventilation, while the last two examples would simply show that the airways were either in a bad condition or far too small for the current that had to pass through the mine.

180. The Inspector having satisfied himself as to the quantity of air passing through the mine, and the amount of resistance it encounters in its passage, he has now to ascertain the amount of force expended in keeping up the ventilation of the mine under such conditions. To ascertain the force expended on ventilation multiply the entire quantity of air passing through the mine by the "Drag," and that product by 5.20, and divide the

sum total by 33,000, and the remainder will be the answer. Example—What is the amount of force expended on the ventilation of a mine where the main air current measures 136,800 cubic feet per minute in the first instance, with a drag of half-an-inch of water-guage; and in the second instance with a drag of 1.75 inches of water-gauge? Here $136,800 \times \frac{0.5 \times 5.2}{33,000} = 136,800 \times \frac{2.6}{33,000} = 10.7784$ H.P. the amount of force expended, and $136,800 \times \frac{1.75 \times 5.2}{33,000} = 136,800 \times \frac{9.1}{33,000} = 37.75$ H.P.

Here the Inspector completes his report, and notwithstanding the good condition of the airways, as illustrated by the first example, he finds that over 40 per cent. of the entire force employed to produce this amount of air current in the mine per minute, is expended in overcoming the frictional resistance alone. Assuming this to be the minimum amount of friction to the circulation of such a quantity of air, and we can assure the reader that we are not inclined to rush to either extreme, in this respect what must he or any experienced agent think of the management of such a mine as represented in the second example, where he finds no less than an additional force of 26.97 H.P. expended in producing the same amount of effective work?

THE SAFETY LAMP.

181. Safety Lamp.—The principle of safety contained in the "Davy" and "Geordy" lamps, was the result of the able researches of Sir Humphrey Davy and Mr. George Stephenson. The former gentleman was a chemist, who enriched the laboratory with deep and profound discoveries of scientific facts, developing principle after principle of the utmost importance to the commercial world; and the latter gentleman was an engineer, who, by his genius and practical skill, as

witnessed in the construction of the steam locomotive engine, has given new life to the industrial enterprise of all nations.

182. The "Davy" lamp consists of three separate sections, the bottom, which is a small cylindrical oil lamp that differs but little from those in ordinary use, except that it is provided with a fine threaded edge by which the upper part is attached to it. The top or frame of the lamp consists of three or four strong wire poles, which are secured at each end to a pair of brass rings 3-8ths of an inch broad and $\frac{1}{4}$ of an inch thick; the bottom ring has a deep border of $\frac{1}{2}$ an inch, and is supplied with a fine box thread, by which means it is attached to the bottom, commonly called lamp. The poles are set in the rings at equal distances from each other, and constitutes the case for the reception of the wire gauze.

The gauze, a wire tube, is passed through the bottom ring till its open end comes in line with the under surface of the frame; at this point it is firmly pressed against the edge of the ring by means of a copper hoop which is thrust into its open end, and its other end fits loosely in the upper ring; a cap is generally provided for the top of the guaze in order to make it stronger, and the summit of the frame is supplied with a brass bonnet commonly called a "Tile." In this position the gauze forms a complete tubular screen around the flame of the lamp and thereby prevents an explosion of gas.

183. Construction of the Gauze.—The safety of the lamp depends upon the construction of the gauze—1st. The wire of which it is made should not be more than 1-50th of an inch thick; 2nd. It should not be more than seven inches long and $1\frac{1}{2}$ inch diameter; and 3rd. It ought not to contain more nor less than 784 cells to the square inch of its surface. By this arrangement the rays of light are conveyed within a given radius from its centre, which enables the miner to perform his work

in a fiery mine, providing that there be a sufficient quantity of air passing through the mine to support the combustion of the lamp.

In consequence of the cells or canals being so small, and iron being a good conductor of heat, neither the flame of the lamp nor the gas which ignites within the gauze can pass through it with a heat sufficient to ignite the gas outside the chamber, for the moment the flame is brought in contact with the gauze, the iron wires, which form the cells by their cross-section, reduces it below white heat and thereby prevents the gas from without being ignited.

184. The "Geordy" lamp differs but little from the "Davy," except that the diameter of its gauze is larger and is supplied with a glass tube of given dimensions, which encloses the flame of the lamp and prevents the gas from rushing through the lower part of its section to the flame.

The lamp is supplied with air by means of a perforated section in the bottom ring of the frame through which also the gas is brought in contact with the flame; and the lamp being proportionately larger than the "Davy," and containing a thick glass tube in addition, it is considerably heavier and costs about one-half more than the ordinary safety lamps, but it must be borne in mind that so long as the gauze and glass tube remain entire, an explosion of fire-damp from it is impossible (see Fig. 17).

185. The safety lamp was never intended by its inventor to be used by workmen in a mine, which is little better than a gas magazine; it was only intended as an indicator of danger from fire-damp, and not by any means as a substitute for good ventilation. If the writer was so disposed, he could easily unfold here a terrible catalogue of colliery explosions which have occurred from this cause alone; but at the coroner's inquest, without one exception, the cause assigned for them was either that a "blower had come off in the

goaf," (a place of course where no one could see it) or that there had been a "sudden outburst of gas." From where? From the goaf or old workings, where it had been allowed to accumulate, "but so far as the ventilation of the mine was concerned, it was always considered to be good." It is in consequence of this fatal mistake that we anxiously press this fact home to the mine-owner, that in consequence of the lives involved, and the capital invested in the undertaking, no workman should be allowed, under any pretence whatever, to remain in a working-place where the gas shows itself in the safety-lamp, as no stronger proof can possibly show that the ventilation of the mine is insufficient than the presence of gas in the workings.

The safety lamp can be used to great advantage, not only as an instrument to test the presence of gas, but as a safeguard to the miner whilst working a broken section on the edge of the goaf, or in a face work situated among local faults where gas is likely to be given off; but in no case should it be made a substitute for good management (see Fig. 17).

BLASTING POWDER.

186. Gunpowder.—The use of gunpowder in mines for blasting purposes is a subject worthy of special notice in a work of this kind. At a very remote date in mining history the use of gunpowder was altogether unknown, and the minerals were got by means of the hammer and wedge; large quantities of minerals were not required, neither indeed could they be supplied in those days, but as time rolled on and the demand increased for mining produce, greater efforts were made by those in charge of such works to augment the production and thereby adjust the supply to the demand. Consequently at a more recent date gunpowder and other combustible ingredients were called to the aid of the miner, in order to enable him to develop more rapidly

the mineral resources of the earth, and thereby to meet the growing requirements of commerce and civilization.

187. The cost of production have, undoubtedly, had a fair share of the attention of both the mine owners and mine managers which have given rise to the introduction of chemical ingredients in mining enterprise. In all metal mines this was essential, and it has been the means of increasing the output in our coal mines at least 50 per cent.; but this fact must not be overlooked, that the use of gunpowder in the production of coal deteriorates its marketable value in some respects as much as 25 per cent. The question, and in our opinion, the all-absorbing question must be raised, what real practical benefit do we derive from the use of gunpowder in the production of coal?

The longwall principle which is being introduced in most of our large mines at the present day, will afford ample scope for testing this subject; and we certainly recommend every mine-owner in this country to try it, believing that the change will be productive of good to both the employer and the employed.

188. Within the last thirty years different kinds of explosive substances have been submitted to the mine-owners in this and other countries, with a view to a more effective force, and one less injurious to the health of the workmen in blasting the minerals, combined with greater economy in the cost of their production, such for instance as gun-cotton, nitro-glycerine, etc., all of which have been fairly tested, and we may say to some extent, with great success.

189. Gunpowder is generally used in the British mines for blasting purposes, and but for the large volume of smoke that always accompany the exploded charge, which is very injurious indeed to the ventilation of the mine, it may be regarded as a valuable ingredient for this purpose; but in consequence of its baneful effects on the health of the miner, who is daily subjected to its influence, and especially in such mineral fields as the Cleveland district,

where some 10,000 lbs. of it is used in the mines daily, it is highly objectionable, and therefore offers high inducements to the chemist to introduce an explosive ingredient that will have the same propulsive force in blasting the minerals without destroying the health and lives of the workmen.

190. Gunpowder consists—by weight of 75 per cent. of saltpetre (Kno.3), 15 of charcoal (C.), and 10 of sulphur (S2), and when kindled, the oxygen of the nitre combines with the carbon to form carbonic dioxide, and the sulphur unites with the potassium of the nitre, whilst the nitrogen, the basis of the nitre is set free.

191. The gases thus formed by the explosion of the powder occupy a space (when at the ordinary temperature of the powder) 400 times larger than the space occupied by the charge before its ignition, but in consequence of the great amount of heat that is produced by the combustion, the gases are expanded in bulk to 1500 times the area of the original charge of the powder, in consequence of which the great propulsive properties it contains are due to the enormous expansive property of the gas it evolves.

192. Nitro-Glycerine.—Nitro-glycerine is an explosive oil of a light yellow colour; it is insoluble in water, and has a specific weight of $1\frac{1}{3}$ times heavier than that fluid; in consequence of this it readily sinks to the bottom of a hole filled with it, and it is beyond all doubt the most effectual stemming that can be applied to the charge.

The oil explodes at a temperature of 360° of Fahrenheit's heat scale, but when it is submitted to the influence of a lighted taper it burns feebly, and if the taper be dipped into the oil and then plunged into the fire, it simply crackles and burns like salt without exhibiting any violent or explosive action.

When the oil is placed in the bore-hole to blast the mineral, the charge is fired either with or without the case, by means of a percussion cap which is attached to the end of a piece of waterproof fuse; the combustion

may be regarded as complete, and no smoke whatever is produced from the charge, but with regard to the gases which are formed by the explosion of the oil, we consider them far from being beneficial to the health of the miner. This was clearly manifested, when three charges were fired in succession in one place in our presence at the Eston mines in 1866. We formed an opinion then, and are of the same opinion now, that the oil is better adapted for sinking pits and open quarry work than for the mines.

193. Gun-Cotton.—Gun-cotton can be used for blasting purposes, either in the yarn or in the compressed block. When used in the yarn for blasting hard rock, we are of an opinion that its combustion is too rapid, and thereby prevents it doing the same amount of effective work that the compressed cotton would do with a less rapid combustion. In the former position it bursts the minerals asunder with great force, but it lacks the cutting property, which is essential to the performance of good work; the compressed cotton is free from this defect, for while it possesses all the force of the yarn cotton in throwing the block in consequence of its slower combustion, it cuts it in such a way as to make the block ready for the next charge that has to follow. This is a great advantage to the workman.

194. The compressed cotton is well adapted for blasting hard rocks, and we think it can be made equal in every respect to the powder for this purpose. Its combustion is all but complete, and no smoke whatever is produced from the exploded charge. In consequence of this, the writer was appointed in 1866, on behalf of Messrs. Bolckow, Vaughan & Co. (Limited), to assist in conducting a series of experiments at their Eston mines, in order to ascertain the difference of the effective force between the gunpowder, gun-cotton and nitro-glycerine, in blasting the iron-stone; and the result of those experiments may be summed up in the following order:—1st. The gun-cotton and nitro-glycerine, with a charge

equal in proportion to the charge of the powder were more economical in cost, the cost being as 6 to 6½; 2nd. The combustion was more rapid in the oil than in the cotton and powder, in consequence of which it failed to perform the same amount of work in the centre block, with a level hole, as the cotton and powder performed under the same conditions; 3rd. The gases formed by the combustion of the three ingredients varied slightly, but the proportion of carbonic-oxide was greater from the oil, this was visibly manifested on several occasions; 4th. That no smoke was visible after the explosion of the oil and cotton, whilst a large volume of it accompanied the explosion of the powder; 5th. The cutting property of the charge was slightly in favour of the powder—where the pellet-grained powder was used—but with the fine-grained powder the cutting property of the charge was in favour of the cotton, but the oil performed the best work with a hole of a dip angular position; and 6th. The effective force produced was greater in the oil and cotton than in the powder, but owing to the powder having a slight advantage over them in its cutting property, the quantity of mineral produced was slightly in its favour.

195. In November, 1866, the writer made an experiment with the yarn cotton in blowing up shale in the waggon way at the same mines. The block was 9 feet broad, 4 ft. thick, and extended some three pillars or 90 yards in length, making a total of about 9700 cubic feet, the whole of which was blown up by 108 charges, consisting of a total of 4320 inches (lineal) of bore hole, charged with 2418 inches of cotton, at a cost of 54s. 6d. The quantity of powder that would have been required for the same number of holes, and under the same conditions, would be 4092 oz., at a cost of 75s., with less than one-fourth the amount of work performed.

This experiment was made with a drill 2½ inches in the chisel, and each hole was bored in a horizontal position from the bottom of the block. In one hole, 66

inches in length, and charged with 54 inches of cotton, the quantity of shale liberated was 300 cubic feet, which took four men eight hours each to break up and store away, and the average amount of work performed was about 90 cubic feet per charge; but it must be borne in mind that the shale was of a tough, woody nature, which gave the yarn cotton a decided advantage over the gunpowder and the compressed cotton with their less rapid combustion; therefore, the experiment clearly proves that whilst hard solid rocks require to be blasted by an explosive ingredient of slow combustion, the more loose stratified measures, such as limestone rock, require to be blasted by an explosive substance of rapid combustion.

DIFFERENT METHODS OF WORKING MINES.

196. Pillar and Stallwork.—Mines which are worked on the pillar and stall principle are divided into two main sections named "Whole" and "Brokens," and their sub-divisions are classified as Headways, Boards, Pillars, Walls, and Stentons in the whole section and in the broken section; or robbing the pillars, as it is sometimes called, they are parcelled off as lifts, juds, sideovers, and jenkings. "Whole" work.—Headways means a narrow section of work on each side of the pits to forewin the measure, and the boards are worked on each side of them; the pillars are the solid blocks of mineral that are left between the boards as supports to the top; a wall is a side cut through the pillars at a given distance from the main headways; and a stenton is a side-cut from one headway to another headway, as the headways are always driven in pairs at a distance of about 10 or 12 yards apart. Brokens.—A lift means a small section of the pillar, and a jud means the same, both being worked from the end of the pillar, leaving the goaf behind, but when sideing over, the goaf is left on one side; and a jenking means a narrow place of

work driven from one end of the pillar to the other end, which serves as a gate road for the ventilating current and the transit of the minerals. The broken section is generally worked about two pillars behind the whole working, and is supplied with a separate current of air, which is passed into the return from that section. The diagram (Fig. 18) will give the student a brief outline of the way in which a mine is worked in this respect:—

D and U represents the downcast and upcast shafts. The air enters the mine through the D pit, and after passing through every section of the workings it returns to the surface by the U pit; DO represents a pair of main separation doors, which are to prevent the air in passing from the D pit escaping to the surface before it has passed through the entire workings of the mine. R represents a regulator which is intended to limit the quantity of air passing into that section of the mine in which it is placed. The arrow points out the course the air is moving; a minus line drawn across an open passage or gate road indicates a stopping; F represents a furnace over which the return air has to pass before it is allowed to ascend the upcast; the X shows how the return current of air passes across the intaken air without being mixed or united with it. The square blocks represent the pillars, and the Boards are represented by BB, which is commonly called a side of work; AA represents the headways; the two small lines across the gate road at the U pit represent a pair of man-hole doors; and the dotted spaces represent the broken section of the mine.

197. The Pillar and Stall Mode of Working Mines.—The method principally employed in our northern coal fields is well adapted for working Royalties under the sea, and with proper management, it may be relied upon as a safe principle in mining operations. It is regarded by mining agents as the oldest method in use in working stratified mines, and up to the year 1760, little or no

attention was paid to it, or to the ventilation; but about this date a Mr. Spedding, of Whitehaven, a gentleman little known in mining history, took the first permanent step toward improving the ventilation, by adopting a method of "coursing the air." To effect this, he built up stoppings in the old board ends, walls, stentons, and headways, which were likely to detract the air from its course, and thereby prevent it from passing around the workings. The late Mr. John Buddle, a colliery viewer in the Northumberland district, at a more recent date, improved upon Mr. Spedding's plan, by splitting the current of air and thus dividing his workings into separate sections. Since Mr. Buddle's day, and we may say within the last 30 years, great improvements have been effected in this respect.

198. The longwall principle, which is more recent than the pillar and stall, is a beautiful system, and is well adapted for working either thick or thin coal mines. The diagram (Fig. 19) illustrates the method in working a mine on this principle—where the gate-roads or headways are driven direct from the shaft to the boundary of the Royalty, at which point a breast of work is opened out, as indicated by the square blocks along the face of work, which are to represent the "Coggs" (in Staffordshire), "Packs" (in Derbyshire), and "Pillars" (in Durham), as supports to the top. The packs or pillars vary in size according to circumstances; where the refuse of the mine is great they form almost an entire breast of work behind the face of coal, but where the refuse is more scarce, they are built up in square blocks of about 81 square feet—the full height of the measure.

199. This method—"working home" as it is called, is generally adopted where the owners have sufficient capital, and can afford to wait until the mine is properly opened out. It is much more costly at the first, but we think we are right in saying that it is the cheapest method in the end.

The references given for (Fig. 18) will apply also to (Figs. 19 and 20.)

200. In (Fig. 20) the principle of working a mine on the longwall, in which the breast of work is opened out on each side of the shafts, leaving only five pillars or 2½ on each side as supports, will convey to the mind of the student - 1st. That the working face is protected along the whole length of the "side of work" by means of the "Coggs," "Pillars," or "Packs;" 2nd. That the gate-road to each section is made in the goaf in the same order and line as seen in the solid blocks around the shafts; 3rd. As the safety of the workmen, as well as the transit of the mineral depends on the strength of the gate-roads, it is necessary to see that the "Goaf" on each side the gateway for a distance of 9 feet at the least, is closely packed; 4th. The two leading stalls, A.A., are intended, as will be seen in the diagram, to open out the entire royalty on each side of the shafts; and 5th. Every gateway that is not in use should be built up closely with fine dirt in such a way as to render them perfectly air tight. By this means, the air is easily conducted through every section of work, which renders an accumulation of gas impossible.

201. Diagram (Fig. 21) gives an end view of a stall in the South Staffordshire thick coal, which is worked on the longwall principle as set forth in (Fig. 19) "working home." The diagram represents a breast of work divided into two distinct sections, containing 25 feet of coal, 6 feet of shale, inter-stratified with the coal, and 10 feet of overlying measures, with four bands of the clay ironstone inter-stratified, and which is known in the district as the ten-feet measure.

202. The upper section, consisting of the white coal, roof coal, and the ten-feet measure is worked off before the bottom section is commenced with. The white coal is underlayed in the heath-coal batt (see a, Fig. 21), which supplies the material for building up the Coggs, as represented by C.C., upon which rests the loose end

of the roof coal and the ten-feet measures. Every fall of the white coal makes room for a cogg nearer the face work, and thereby enables the miner to take down the roof coal from off the inner cogg, which liberates the over-lying measures, and brings them within reach of the workmen. As soon as the falling off of the upper measures have subsided, the stone-men go to work between the coggs, as represented by H.H., to pick off the ironstone bands.

203. The bottom section which embraces seven sections of the measure, is a more complicated and difficult principle of operation, and is attended with greater risk to life than the other section. For the convenience and safety of working the different section it contains, it is divided into two parts known as the "Navvy" and "Waste." The Navvy embraces the dice, slipper, and sawier sections. The dice coal is of little worth as fuel, and is therefore used with other refuse, such as shale, to build up the coggs behind the face work, which are an excellent substitute for timber.

The Patchel is a fine strong measure; it forms the basis of the second group, and serves as a roof to the navvy; its B loose end or the end next the goaf rests on the coggs CC and is drawn off with the veins by removing the upper part of them; when this is done, and the patchel is undermined, the measure gradually weighs off in lengths varying from six to nine feet. The tow and heath coal measures are worked off on the same principle as illustrated by the waste section (WC), and in consideration of the extra danger the wastemen are exposed to, they are paid from 1s. 4d. to 1s. 6d. per day more than the navvy and stallmen, a privilege they justly merit.

204. The square work principle is a more dangerous mode of working than either the pillar and stall or long wall methods in working a thick coal mine, and in addition to this, the loss of minerals in the South Staffordshire thick coal mines, where it is in full

operation, can not be less than from 30 to 40 per cent. of the entire area of Royalty worked.

A prominent reason is set forth by the supporters of this theory, that they can produce a better marketable coal by the square work principle than they can produce by the long wall method; this statement, however, is not supported by facts In 1871 the writer made a series of experiments in the Cradley district, where he found that the coal on the longwall method was 3.72 of large against 1 of small, and that on the square work method 2.95 of large against 1 of small, thus making a difference of 0.77 in the produce of large coal against the small or sleck in favour of the longwall principle. Those results were taken from the produce of two collieries for 20 days, in which the writer considers that the difference of 0.77 is rather under than over the yearly average.

FIRE-CLAY, OR GANISTER.

205. Fire-clay generally lies under the coal; sometimes, however, it divides the measure and forms an intermediate section in the seam, as in the Bensham and Main coal in the north of England; in this position it is worked with the coal, and either sent to the surface for manufacturing purposes, or is stored away behind the face-work.

In some seams it forms the floor of the measure, and is worked at a distance of one pillar behind the face-work, but where it can be worked with the coal and made the shorting measure of the seam it is well to do so, because, it will not by any means deteriorate its quality, while it will at the same time materially enhance the commercial value of the coal seam.

206. The quality of fire-clay varies with all the coal measures in which it is found. In the south Durham coal field, a large quantity of excellent fire-bricks are made in the district of Crook, which in the opinion of

experienced persons, is regarded as a fair sample of our best clay in the northern counties, but of course, it falls far short of the quality of the Stourbridge clay. The Stourbridge clay is undoubtedly the best fire-clay in this country. The chemical analysis defines its composition thus:—Silica, 64; Alumina, 23; Oxide of Iron, 2; Water and organic matter, 11=100; but it must be understood that the quality of the clay differs in some respects even in the same mine, which may be seen from the following statistics taken from a royalty in east Worcestershire, near Stourbridge, as the production of two fire-clay pits, from the 1st July, 1869, to the 10th of May 1870:—

	T.	Cwt.		T.	Cwt.		T.	Cwt.
Yield of A pit—Best	401	16	Seconds,	25	5	Offal,	2223	3
Do. of B „ „	773	9	„	150	10	„	3165	7
Total produce, ..	1175.	5		175.15			6388.10	

In this example the proportions are 6 of best to 1 of seconds, and 4.7 of offal to 1 of best and seconds jointly. The terms however, "best," "seconds," and "offal," convey to our mind something more than the mere fact that three separate and distinct qualities of the clay are found in the same measure, for while the commercial value of each quality vary, say from 7s., 21s., and 33s. per ton respectively, the cost of their production is the same throughout. In the formation of fire-clay there can be little doubt that it is the result of the original soil upon which the plants now forming the coal measures grew, as it is full of stigmaria and other roots of plants which belong to the carboniferous measure. Its quality depends upon the amount of silica and alumina it contains; the former is widely diffused through the earth's crust, and is very conspicuous in sand, sandstone, granite, gneiss, and trap-rocks, whilst the quartz are really pure silica; the latter substance, alumina, occurs native, and forms the mineral corundum, the sapphire and ruby, whilst the more crystallized varieties go to constitute the

emery which is so largely used for polishing purposes, but when it assumes the form of an aluminic silicate, it is in various minerals such as felspar and clay.

From what has already been said with respect to this important mineral fire-clay, and taken into consideration its commercial value in the construction of puddling and blast furnaces, the manufacture of gas retorts and fire-bricks alone, is sufficient to justify great care on the part of the manager with regard to its production.

IRONSTONE.

207. Iron, like copper, is found native in very small quantities, but in combination with other ingredients, is widely distributed through the mineral formations, either as oxides or carbonates of iron ore. The oxide iron ore is naturally divided into a series of separate and distinct classes as black oxide (Fe3 O4) or magnetic iron ore, and red oxide (Fe2 O2) or hematite iron ore.

The magnetic ore is a compound of the sesquioxide and protoxide of iron, in consequence of which it is highly magnetic and exceedingly rich in metal. Its metallic percentage varies, but when found pure it contains upward of 85 per cent. of iron, and in the common ordinary condition in which it appears will yield on an average as much as 68 per cent of iron of a very superior class.

The red hematite ore is an anhydrans sesquioxide of iron of a fibrous structure. It is much more largely distributed, but is slightly inferior in quality; when found absolutely pure, it will yield as much as 70 per cent. of iron, but on an average it will not yield more than 50 per cent. of iron, which is also of a superior quality. This ore is charateristically known by many names, such as "kidney" and "pencil" ore, and when it is crystallized it is called "specular" iron ore.

The brown hematite ore is a hydrated sesquioxide of iron, and is much poorer in quality than either of the

ores above named. It is, however, a valuable ore to the iron manufacturer, who mixes it with other inferior ores for the manufacture of a medium quality of iron. Its metallic percentage varies from 35 to 50, and may be taken to yield on an average 40 per cent. of iron.

The distribution of the oxides are marked by special peculiarities, not only with respect to the different periods and modes of their depositions, but to the agency employed to effect the same.

They occur in the "Laurentian" rocks of Canada and Scotland, the lowest stratified measure of the *primary period*, interstratified or associated with limestone; in the "carboniferous" rocks of Cumberland, North Lancashire, and Forest of Dean, interstratified or associated with the mountain limestone; and in the "oolite" measure of the *secondary period*, associated with sand and gravel in Northampton and Lincolnshire.

In addition to those localities the ores are deposited over thousands of acres of land, both in Sweden, Germany, India, and North America, in varying proportions from a mere trace to beds over 200 feet in thickness.

These ores are found under three separate and distinct conditions—either in *lodes*, which is considered to be the result of "Igneous" agency, or in *pockets* or *beds*, which is also regarded by high authority as the result of "aqueous agency, and it is only when the ores appear in the two last named positions that their thickness is sufficient to justify working them on a large scale.

208. Ferric-Sulphide (Fe. S2.) or Iron Pyrite is sparingly distributed in the Oolitic, Liassic, and Carboniferious formations, but it cannot be reduced to a pure iron by any known process. It contains a large amount of sulphur in its composition, in consequence of which it can be applied to the manufacture of copperas, sulphate of iron or green vitriol at a light expense, but the only benefit that may be expected from the sale of this ingredient is, that it may partly defray the cost of

separating it from the minerals already named.

209. Ferrous Carbonate (Fe. Co3) or Clay Iron Stone.—The carbonates, like the oxides, appear in varying conditions and in separate and distinct sections, as black and brown carbonates of iron ore—the principal constituents of their composition consists of protoxide of iron and carbonic acid, with varying proportions of argillaceous and carbonaceous matter.

The black carbonate belongs more immediately to the coal measures, but the brown carbonate is found in nearly all the measures, and their metallic per cent. varies from 38.4 to 21, but they will not yield more on an average than from 30 to 33 per cent. of iron. They are characteristically known in South Wales as the "Pins" and "Books;" in South Staffordshire as "White-stone;" in Derbyshire, Lancashire, and Scotland as "Black-band;" in Durham and Northumberland as "Iron Bands;" and in Cleveland as "Lias Ironstone."

These ores vary in thickness from half an inch to half a foot in the coal measures, but in the Cleveland district they arrange from 4 feet to 17 feet, and at Rosedale to more than double this thickness.

The argillaceous ironstone of Cleveland is a member of the carbonates, and belongs to the "Lias" measure, which forms the upper and lower portion of the "jurassic system" of the *secondary period*, and is partly of "marine," partly of "esturine," and partly of "terrestrial" formation. The metallic per cent. of this ore varies from 20.25 to 33.25, and will yield on an average about 28 per cent. of iron. Its distribution extends over an area in Cleveland and Rosedale of about 100 square miles, and will yield about 20,000 tons per acre. In some parts of the district it is interstratified with a band of shale, varying in thickness from one-fourth of an inch to two feet and upward, so that under such conditions it must be evident that those royalties where the metallic per cent. is less than 28, and others with a band of shale dividing the main block of stone, cannot be worked

profitably till the stone near the coast, which is free from these defects, is considerably reduced.

ROCKSALT AND GYPSUM.

210. Rocksalt and Gypsum beds are formed by the residuum of water which contains in solution those minerals which go to constitute them.

The water is supposed to have flowed through a channel into a low district of land which did not provide an outlet for the current, consequently the body of water in the trough gradually became more and more impregnated with the minerals with which it was already saturated ere it reached the basin, and still further aided by the constant process of vaporation, which must have kept pace with the current, would cause a gradual deposition of them, so that in the course of time, these low portions of land · that were the receptacle of the minerals would be filled up to the level of the channel, which would prevent further ingress of the water, and thereby limit the accumulation of the mineral to the area of the district over which the water had flowed.

211. Gypsum (Ca. S04+2 H20) generally appears with rocksalt (Na. Cl.), associated with Keuper Marl, which forms an intermediate measure between the "Lias" and "Permian" formation, and belongs to what is "geologically" called the "Triassic" period.

These minerals are deposited in different parts of England, as in Chester, Droitwich, Westmoreland, Cleveland, etc., but are only worked to a very limited extent, and that too for the manufacture of composts and artificial manures. In the last-named district they attain a thickness of about 100 feet each, the former, though greatly mixed with the Keuper Marl, possess a fine section six feet thick of pure gypsum, whilst the latter, so far as the bore-hole of Messrs. Bolckow, Vaughan and Company, at Middlesborough, reveals, it is of an excellent quality throughout the entire measure.

212. The gypsum and salt rock beds are worked on the same principle as the coal measures, and owing to the tough nature of the marl with which they are associated, they require but little or no timber to support the workings.

213. Gypsum (sulphate of lime), better known to the miner as "Plaster of Paris," but classically to the chemist as "Stucco," is a valuable mineral, and when produced pure, it finds a ready market for its consumption in the manufacture of ornamental goods, cornice, etc. It has been worked in Cleveland to a small extent, but there has never been sufficient capital invested in the undertaking to make it a profitable business.

214. Rocksalt (Sodic Chloride) is the principal constituent of sodium and chlorine, and forms a number of valuable compounds, such for instance as sodic carbonate, which is largely consumed by manufacturers in their different works as bleaching powder, and in the manufacture of soap, glass, washing-soda, etc. (see 137-8).

ALUM AND JET SHALE.

215. Alum shale or alum chist, is largely distributed in the "Lias" formation. It rests on what is commonly called the jet shale, but classically termed the "Cephalopoda beds" (an order of the Mallusca animals with soft bodies, embracing the cuttle fish with tentacles around the mouth), and is found in many parts of the Cleveland district from 20 feet to 60 feet thick.

Alum shale has been worked extensively at Bowlby, and near to Guisborough, but at the former only within the present generation; and owing to a change in the manufacture of alum, ammonia alum, Al(H4 N) (S O4) 2, has of late years been substituted in place of common alum, in consequence of which these works have been closed as un-remunerative for ten or twelve years.

216. Jet shale is a measure which overlies the Lias ironstone, and is found to be generally about 10 feet

thick. It is a very soft tender measure, and requires considerable timber to support the workings, unless the mineral is got by means of an open cutting.

The jet is a black carbonized fossil substance, susceptible of a very high polish, and is principally used in jewellery and ornamental goods.

WATER.

217. Water (H2 O.), hydric oxide—when pure, consists of oxygen and hydrogen only, in the proportions of 8-9ths of the former and 1-9th of the latter, and which is the standard of comparison in weighing liquids and solids, but in consequence of its close connection with the mineral, vegetable, and animal formations of the earth, it cannot be obtained from nature either as sea or spring water absolutely pure.

Chemical analysis defines the different ingredients which are found in solution in 1000 parts of water in the following order: -

Sea Water contains		Spring Water contains	
Water, ...	962.5	Water, ...	998.5
Sodic Chloride, ...	29.0	Calcic Carbonate, ..	0.8
Calcic Sulphate, ...	1.5	Calcic Sulphate, :	0.4
Magnesia Chloride, ...	4.0	And small portions of other salts,	0.3
Salts of Bromide, Iodides, &c., in small quantities	3.0		
	1000.0		1000.0

Water, apart from those impurities, is often contaminated with animal and vegetable matter which is much more serious, and which shows the necessity of having all waters properly filtered that are intended for drinking purposes or domestic use.

218. Where water is hard or discoloured it is in consequence of the mineral, vegetable, or animal matter it holds in solution, all of which may be easily detected by mixing a few drops of baric chloride, or argentic nitrate or ammonia, or ammonic oxalate with a glass full of

water for each separate test, when the impurities will appear, if there at all, either as a precipitate or as a dull heavy cloudiness in the vessel, the most of which can be got rid of by means of boiling, but if absolute purity is required, the water must be distilled.

219. Water of the mines should be submitted to the same analytical test as the water of the surface, although as a rule, it is not used for drinking purposes, but for the safety of the workmen as well as for general information this should be done.

SURVEYING.

220. The object of underground surveying, is to keep a proper illustrated record in the office of all minerals in the Royalty, showing the different methods employed to work them; the quantity of minerals got in each section of the Royalty per annum; the local and general interruptions to the measures, and a perfectly accurate outline of the boundaries.

221. The Chain.—Gunters chain is commonly used in taking the dimensions of land; it contains 100 links, each link and the three small rings that couple the links together, measure 7.92 inches. At the end of every ten links is attached a piece of brass (each piece varying in shape) for the more readily counting the odd links at the off sets or end of the distance of each station line. The 100 links are equal to 66 feet or 22 yards; and as an acre of land contains 4840 square yards or 100,000 square links the measurement of land is easily obtained by it. One square chain is equal to one-tenth of an acre, and ten square chains contains the same number of yards as an acre of land contains—4840.

222. When surveying the surface of a Royalty—if the content of the field's measurement be cast up in square links and divided by 100,000, or (what is the same thing) if the last five figures be cut off, those remaining on the left hand will give the content in acres, and the

remaining figures on the right hand will be decimal fractions of an acre, which, if multiplied by 4, cutting off the five last figures as before mentioned, these on the left hand will give the content in roods, and the remaining figures to the right will be decimal parts of a rood; and to complete the process, if the decimals of the rood be multiplied by 40, cutting off the last five figures as above-named, those to the left hand will give the content in poles or perches.

The following example will more clearly illustrate the principle to the mind of the student:—How many acres, roods and perches are there in a field the superficial area of which contains 980,000 square links?

Here 9,80000
4
3,20000
40
8,00000
Answer—9a. 3r. 8p.

FIVE-INCH THEODOLITE.

223. The Theodolite, as an angular instrument, is the one most commonly used in large and well regulated mines. It consists of two circular plates—A and B (Fig. 22), which are called the horizontal limb, the upper or vernier plate A turning freely upon the lower, and both have a horizontal motion by means of the vertical axis C. This axis consists of two parts, external and internal, the former is secured to the graduated limb B, and the latter to the vernier plate A, both being nicely ground and fitted into each other, so that they have an easy and steady motion. The external centre fits into a ball at D, and the parts are held together by a screw at the lower end of the internal axis.

224. The diameter of the lower plate is greater than that of the upper one, and its edge is chamfered off, and

covered with silver to receive the graduations; on the opposite parts of the edge of the upper plate, or 180° apart, a short space (a) is also chamfered, forming with the edge of the lower plate a continued incline plane. These spaces are likewise covered with silver and form the verniers.

225. The parallel plates F and G are held together by a ball and socket at D, and are set firm and parallel to each other by four milled headed screws, three of which, c, c, c, are shown in the figure. These turn in sockets fixed to the lower plate, while their heads press against the underside of the upper plate, and being set in pairs opposite each other, they act in contrary directions. By this means the instrument is set up level for observation.

226. Beneath the parallel plates is a female screw, adapted to the staff head, which is connected by means of three brass joints to three mahogany legs, so constructed that when shut up they form one round staff, and when opened out they make a very firm stand, be the ground ever so uneven.

227. The lower horizontal limb can be fixed in any position by tightening the clamping screw H, which causes the collar c to embrace the axis C, and prevents it moving; but as great accuracy is required in fixing the instrument on the line of collimation, a slow motion screw (I) is attached to the upper parallel plate, which moves the whole instrument to the finest point; in like manner the upper or vernier plate A, can be fixed to the lower plate B in any position by a clamp (in the figure this clamp is concealed from view), which is also furnished with a slow motion, the screw of which is generally called the tangent screw.

228. Upon the plane of the vernier plate, two spirit levels d d are placed at right angles to each other, with their proper adjusting screws; a compass is also placed at J, which in some respects, such as giving the surveyor

an idea of the polar line of an object if he require it, may be used to advantage.

229. The frames K and L support the pivots of the horizontal axis of the vertical arc (or semicircle) M, on which the telescope is placed. The arm which bears the microscope N for reading the altitudes or the depressions, measured by the semicircle, and denoted by the vernier (e), has a motion of several degrees between the bars of the frame K, and can be moved before the face of the vernier for reading it off. Another arm clamps the opposite end of the horizontal axis by turning the screw O, and has a tangent screw of slow motion at P, by which means the vertical arc and telescope are moved very small quantities up or down to perfect the contact when an observation is made.

230. One side of the vertical arc is inlaid with silver and divided to single minutes by the help of its vernier, and the other side shows the difference between the hypotheneuse and base of a right angled triangle, or, the number of links to be deducted from each chains' length, in measuring up or down an inclined plane to reduce it to the horizontal measure. The level, which is shown under and parallel to the telescope, is attached to it at one end by a joint, and at the other by a capstan headed screw (f), which being raised or lowered will set the level parallel to the optical axis of the telescope or line of collimation; the screw (g) at the opposite end is to adjust it to the true parallelism in this respect.

231. The telescope has two collars or rings of bell metal, ground truly cylindrical, on which it rests in its supports, (h h) called Y's from their resemblance to that letter; and it is confined in its place by the clips (i i) which may be opened by removing the pins (j j) for the purpose of reversing the telescope, or allowing it a circular motion round its axis during the adjustment.

232. In the focus of the eye-glass are placed three lines, formed of spider's web, one horizontal, and two crossing it, so as to include a small angle between them,

a method of fixing the wires which is better than having one particular wire, because an object at a distance can be made to bisect the said small angle with more certainty than it can be bisected by a vertical wire. The screws adjusting the cross-wires are shown at (m); there are four of these screws, two of which are placed opposite each other, and at right angles to the other two, so that by easing one and tightening the opposite one of each pair, the intersection of the cross wires may be placed in adjustment.

233. The object glass is thrust outwards by turning the milled head Q, on the side of the telescope, that being the means of adjusting it to show an object distinctly.

234. The adjustment of the instrument is that of the line of collimation; that is, to make the intersection of the cross wires coincide with the axis of the cylindrical rings on which the telescope turns. It is known to be correct when the air bubble of the level remain in the centre of the glass or tube, when an eye looking through the telescope observes their intersection continue on the same point of a distant object during its entire revolution.

235. Set the instrument as nearly level as can be done by the eye, then fasten the centre of the lower horizontal limb by the staff head clamp H, leaving the upper limb at liberty, but move it till the telescope is over two of the parallel plate screws, then bring the bubble of the level under the telescope, to the middle of the tube by the screw P; now turn the upper limb half round, that is to 180° from its former postion; then, if the bubble returns to the middle, the limb is horizontal in that direction; but if otherwise, half the difference must be corrected by the parallel plate screws over which the telescope lies, and half, by elevating or depressing the telescope by turning the tangent screw of the vertical arc P; having done which, turn the upper limb forward or backward 90° that the telescope may lie

over the other two parallel plate screws, and by their motion set it horizontal. Having now levelled the limb plates by means of the telescope level, which is the most sensible upon the instrument, the other air bubbles fixed upon the vernier plate may be brought to the middle of their tubes, by merely giving motion to the screws which fasten them in their places.

236. In reading of the angle of observation, great care is required to have the object perfectly intersected by the cross wires of the eye-glass, otherwise a correct survey can not be made.

237. The following diagram (Fig. 23) is intended to illustrate the method in reading the angular bearing of the instrument from a given point, where A B represents the degrees and minutes on the upper, and C D, the seconds on the under part of the horizontal line, which is to represent the graduated margin or border of the horizontal limb B and the vernier plate A of Fig 22.

238. Each degree from 60° to 64° is divided into six parts as seen by the short lines, and each of those parts represents 10′ or (ten minutes) the third line of each division being longer than the other two represents 30′ or half a degree.

The short lines on the vernier C D represents also a division of each minute into six equal parts, each part representing ten seconds, the third line being rather longer represents 30″ or half a minute.

239. To read the instrument or the angle of the object you have correctly bisected, find the number of degrees and minutes on the right hand side of the 0 or zero of the vernier C D, and if the lines representing the minutes do not coincide with the zero line of the vernier C, it is evident you must find the remaining part of the angle of your observation by the vernier, in which case you must carefully scrutinize every line from zero at C toward D till you find a line on the vernier that coincides with a short line on the upper division, as represented by E, in which case you will count the number of

divisions from 0 to E, and if the divisional lines exceed six and do not extend to twelve, you will in this case have one minute and so many seconds, in addition to the number of degrees and minutes you found on the right side of the vernier 0, at the beginning of your reading off the bearing of the instrument; in which case the answer would be as set forth in this diagram—60°, 21′, 20″:

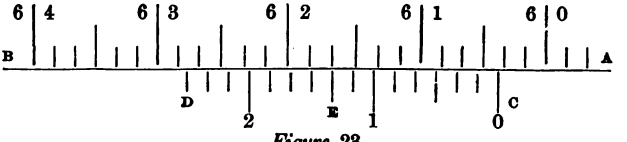


Figure 23.

240. When the lines C D do not coincide with the lines A B in any respect, but falls between them, the number of seconds in that division will be less than 10″, so that if the supposed E line C D fall midway between two of the short or minute lines A B, the vernier reading would be 5″, but if it fell one-fourth or three-fourths of the distance in the space between them, the reading would be $2\frac{1}{2}$″ or $7\frac{1}{2}$″, and in such cases the readings of the seconds by the vernier varies in proportion to the distance between two minute lines in which the supposed E line C D falls. By an eye and hand properly educated to the use of the instrument, a survey of a Royalty of 2000 acres can be made either in the mine or at the surface within an error of two minutes.

241. Field Book.—The angular bearing of the instrument at each station or set must be correctly entered in the field book, as read off from the horizontal limbs A B at the vernier (a), in the same form as contained in the last paragraph—Fig. 23, 60° 21′ 20″; and the angle of elevation or depression should also be entered in the second column of the book, as read off from the vertical arc (or semicircle) M at (e) by the microscope N,

which enables the surveyor to reduce the incline measure to the horizontal measure at each distance throughout the entire survey. The following table will more clearly illustrate this principle to the mind of the student:—

Table showing the reduction in links and decimals of a link upon 100 links for every half degree of inclination from 3° to 20°-30′:—

Angle.	Reduction.	Angle.	Reduction.	Angle.	Reduction.
d. min.		*d. min.*		*d. min.*	
3 0	0. 15	9 0	1. 23	15 0	3. 41
,, 30	0. 19	,, 30	1. 37	,, 30	3. 64
4 0	0. 24	10 0	1. 53	16 0	3. 87
,, 30	0. 31	,, 30	1. 67	,, 30	4. 12
5 0	0. 38	11 0	1. 84	17 0	4. 37
,, 30	0. 46	,, 30	2. 01	,, 30	4. 63
6 0	0. 55	12 0	2. 19	18 0	4. 89
,, 30	0. 64	,, 30	2. 37	,, 30	5. 17
7 0	0. 75	13 0	2. 56	19 0	5. 45
,, 30	0. 86	,, 30	2. 76	,, 30	5. 74
8 0	0. 97	14 0	2. 97	20 0	6. 03
,, 30	1. 10	,, 30	3. 19	,, 30	6. 33

TO FIND THE MECHANICAL FORCE FOR PUMPING AND WINDING PURPOSES.

242. Force.—Mechanical force is calculated from a given weight being lifted a given height per minute, in consideration of which 33,000 lbs. lifted one foot high per minute, is regarded in all mechanical calculations on force, as being equal to one-horse power, and which is represented by H.P.

243. Mechanical calculations on the force of steam engines are based on the fact, that a given amount of water vaporated or converted into steam, produces a force proportionate to its volume contained in a given space.

244. The mechanical force developed by the process of vaporation, is proportioned to the quantity of water converted into steam in a given time; that is to say, that one cubic inch of water vaporated into steam and applied to an object at once, contains a force within its volume under a given pressure sufficient to raise a ton weight one foot high.

245. The duty of a steam engine is regarded from the effect it produces with a given weight of fuel without reference to time, but the force or power of an engine is estimated by the mechanical effect it is capable of producing in a given time; so that in the former it is immaterial whether a ton of coals raise 800 tons a foot high in one hour or in ten hours, but in the latter the ton of coals is expected to raise the load in a given time to a given height.

246. A large percentage of the force generated by the vaporation of the water in the boilers, is expended before it reaches the actual point of work assigned to it. This is due—1st, to the force required to give motion to the engine; 2nd, to a partial condensation of the steam before it reach the cylinder; and 3rd, to the amount of friction caused from the motion of the machinery and its load, in consequence of which it is customary for engine-makers to allow from 30 to 40 per cent. off the mechanical force developed by the vaporation. Under such conditions and with such an allowance, one cubic foot of water vaporated or converted into steam in one hour, is regarded by mechanical engineers as being equal to one-horse power.

247. The vaporation of water is as much due to the construction of the boiler as to the formation of the furnace. Under such circumstances, engineers consider that the diameter of the boiler should not exceed one-sixth its length, but it would be all the better for many reasons if its diameter was not more than one-eighth its length.

248. The amount of working power in the steam

engine depends on the area of the piston, the length of its stroke, the pressure of the steam (less the atmospheric pressure), and the speed or number of feet the piston is travelling in the cylinder per minute.

249. If the area of the piston be 1000 square inches, the pressure of the steam 45 lbs. per square inch, the length of the stroke 5 ft., and number of strokes 20 per minute, what ought to be the horse power of an engine under such conditions?

Example :—$1000 \times 30 \times 5 \times 20 = 3{,}000{,}000 \div 33{,}000 =$ 91 H.P. nearly. In consequence of the loss of power from the different causes set forth in 246, against which no provision has been made in this example, the result obtained simply gives the theoretical horse power of the engine.

250. There are a number of methods in use to calculate the horse power of engines, all of which differ slightly from each other; but the common principle that is most generally used, and which we consider sufficient for all practical purposes, is as follows:

Rule—Multiply the area of the cylinder by the pressure of steam per square inch (less 15 pounds atmospheric pressure), and that product multiplied by the speed of the piston per minute, will give the entire units of work done in that time; and this sum divided by 33,000 units, will give the horse power of the engine required.

The following example will more clearly illustrate the principle:—

What is the horse power of an engine, the diameter of the cylinder being 26 inches, the pressure of the steam 45 pounds per square inch, and the speed of the piston 120 feet per minute?

Here $26 \times 26 \times .7854 = 530.9304$ square feet, the area of the cylinder; and $530.9304 \times \frac{30}{33000} = 57.919$ horse power.

To find the horse power of a low pressure engine, where the pressure of the steam is not more than 21 or

22 pounds per square inch, and the speed of the piston about 200 feet per minute: Divide the area of the piston by 22 square inches, and the quotient will give the horse power sufficiently accurate for all practical purposes.

To find the horse power of an engine for pumping water, or lifting minerals from a mine:—

251. Ascertain the number of units in pounds per minute of each class of material, and that sum multiplied by the depth of the shaft in feet, divided by 33,000, will give the horse power required for the work.

Example: What must be the horse power of an engine to lift 3000 gallons of water per minute from a mine 300 feet deep: a gallon of water = 10 pounds?

Here $3000 \times \frac{10 \times 300}{33000} = 3000 \times \frac{3000}{33000} = \frac{9000000}{33000} =$ 272.7 horse power, the answer required.

A series of exercises are here submitted for the benefit of the young student, to aid him in studying the different subjects contained in this treatise; and, in the meantime, the author begs to state, that he has used unsparingly every information he has been able to obtain, from whatever source it may have come within his reach, in order to make the work interesting and instructive to the class for whose safety and welfare it is especially intended. Believing, as he does, and he speaks with an experience of over fifty years on the subject, that nothing can conduce to greater safety and economy in the working of our coal mines, short of a thorough practical supervision of every section of the surface and underground workings. Therefore, he holds that it is the duty of every mine owner to bring his intelligent workmen forward from a lower to a higher office, until the entire management of the colliery is placed in the hands of one of the most intelligent and experienced workmen in his employ.

A series of questions are submitted as exercises to the student while studying the various subjects contained in the work.

ATMOSPHERE.

	Paragraphs.
1. Describe the atmosphere from its appearance?	2.
2. State its general properties that come within the range of our senses? ..	3, 4.
3 What is its ordinary pressure on man?	5.
4. Describe the relative density of the atmosphere?	6.
5. Is its density uniform?	6, 7.
6. How was the variations of atmospheric density discovered?	8.
7. Describe its elastic properties? ..	18, 19.
8. By what means is its pressure tested?	9, 10.
9. In what respect does the temperature effect its density?	11.
10. Describe the relative difference of pressure between water, mercury, and air?	12, 13.
11. In what respect does its pressure effect a syphon, or a pumping apparatus?	14, 17.
12. Under what conditions is aqueous vapour associated with the atmosphere?	20, 23.
13. How is heat diffused through the atmosphere?	24, 25.
14. What is the difference between latent and sensible heat?	26.
15. By what means do you test the heat contained in a substance?	26, 27, 32.
16. Under what conditions is heat communicated to bodies?	28, 31.
17. Describe the properties of the Fahrenheit and Centigrade Thermometers?	32, 35.
18. Is the atmosphere a simple or compound body?	36, 38.

	Paragraphs.
19. Define its composition?	39.
20. Are the constituent elements of the atmosphere combined chemically or mechanically?	40.
21. Can anyone of its constituents support life long?	41.
22. What is Oxygen?	42, 43.
23. Describe how, when and by whom was it discovered?	43, 44.
24. Define its properties and how prepared?	45, 47.
25. What is Nitrogen or Azote? ..	48, 49.
26. State its properties	50, 52.
27. What is Carbonic Dioxide?	53, 96.
28. Describe its properties?	54, 97, 99.
29. How is the gas prepared?	55.
30. What is Ammonia?	56.
31. Define its properties.	57, 58.
32. How is the gas prepared?	59.
33. Can it in any way improve the conditions of the atmosphere? ..	60.
34. By what means is its presence in the atmosphere detected?	61.

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36. What quantity of air does a horse require per minute?	76.
37. What is the minimum quantity of air required per minute for a man, horse and candle?	79.
38. State what quantity of air an adult person should have per minute in a mine that gives off little or no gas?	80.

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40.	Are the gases governed by the law of gravity in the same order as other bodies?	63, 65.
41.	Describe the way in which they unite with each other?	66, 72.

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43.	What is Methylic Hydride?	83.
44.	Define its properties?	84, 86, 89.
45.	What effect does it produce on the miner if breathed for a few seconds?	85.
46.	How is the gas prepared?	88.
47.	What is the kind of heat that ignites the gas?	183.
48.	What is Ethylene?	90.
49.	Describe its properties?	91, 93, 95.
50.	How is the gas made?	94.
51.	What is Carbonic Oxide?	100.
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53.	State how the gas is prepared. ..	104.
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55.	Define its properties.	106, 111.
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67. Define the properties of inertia and motion. .. .. 146.
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72. What is meant by the word elasticity? 149.
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